

ICESat SIPS SOFTWARE CRITICAL DESIGN REVIEW

Day 2

**November 30 - December 1, 1999
9:00 a.m.**

Goddard Space Flight Center, Building 6 Room W137

GLAS WAVEFORM AND ELEVATION ALGORITHM AND PRODUCT SUMMARY

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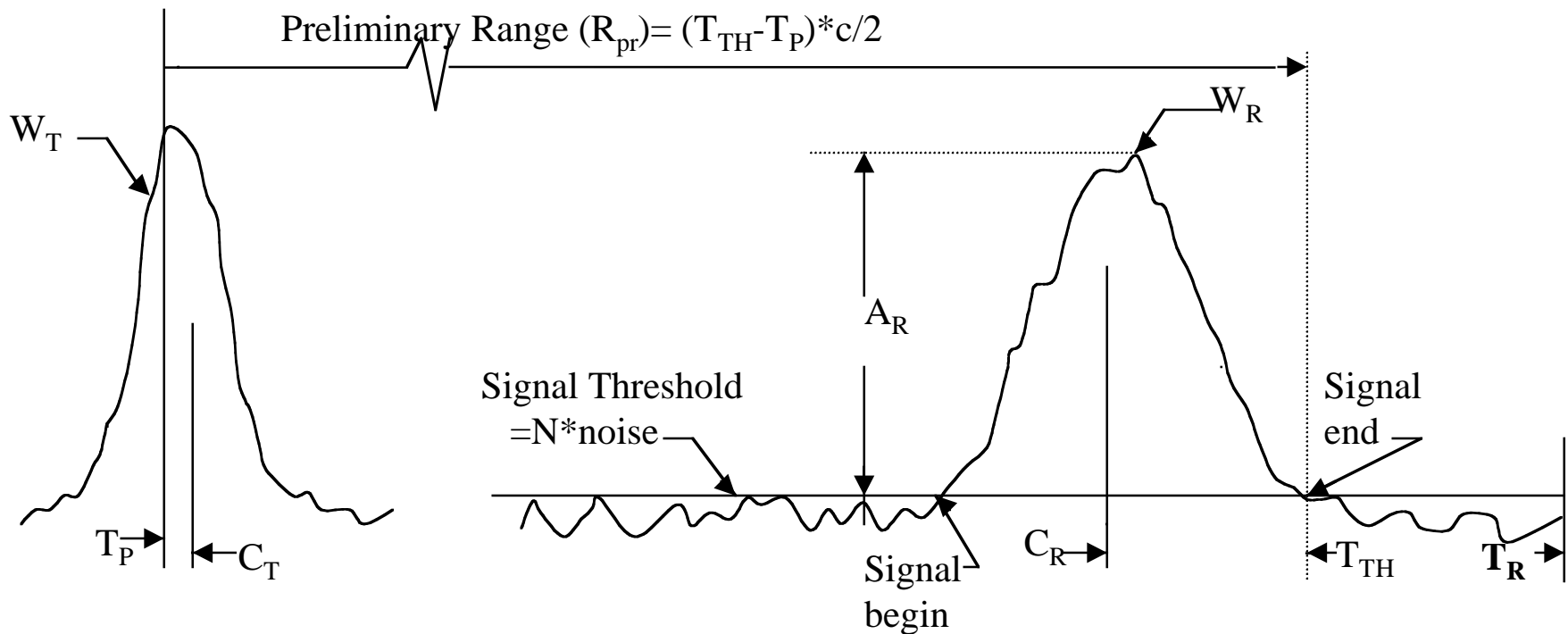
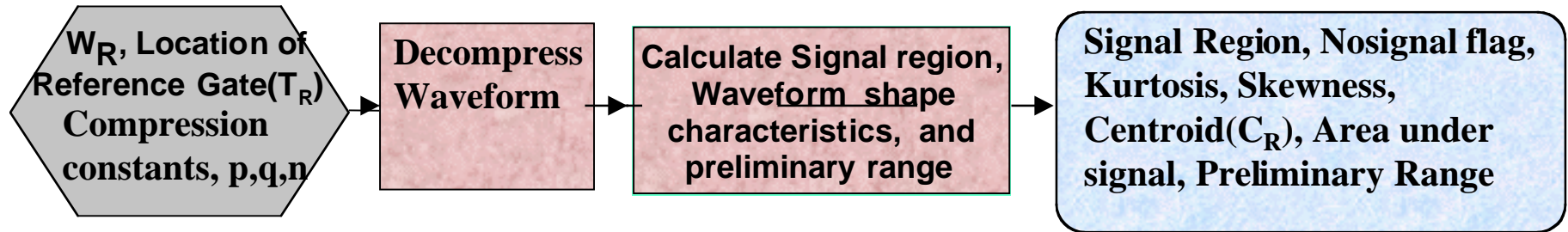
GLAS WAVEFORM AND ELEVATION PRODUCTS

Level 1a - GLA01	Level 1b - GLA06	Level 2 - GLA12-15 Regional products for ice sheet, sea ice, land, and ocean
<ul style="list-style-type: none"> •Transmit waveform •Received waveform •Instrument parameters pertinent to altimetry 	<ul style="list-style-type: none"> •Corrected preliminary surface elevation •Footprint location •Elevation distribution within footprint •Laser off-nadir pointing •Spacecraft orbit •Corrected Range •Atmospheric delay •Tidal Values •Increments to calculate mean surface elevations •Geoid •Elevation quality flags •Waveform quality flags •Atmospheric condition flags •Reflectance estimate 	<ul style="list-style-type: none"> •Corrected surface elevation •Footprint location •Elevation distribution within footprint •Laser off-nadir pointing •Spacecraft orbit •Corrected Range •Atmospheric delay •Tidal Values •Geoid •Elevation quality flags •Waveform quality flags •Atmospheric condition flags •Reflectance estimate •Region-specific output
Level 1b - GLA05		
<ul style="list-style-type: none"> •Transmit waveform characteristics •Received waveform characteristics •Waveform quality flags •Preliminary range and footprint Location •Laser off-nadir pointing •Spacecraft orbit 		

WAVEFORM ALGORITHM IMPLEMENTATION

- **Algorithm Ground Rules**
 - **One algorithm will be used to process data over all surface types.**
 - **Algorithm will be driven by a surface-dependent parameter file.**
 - **one set of parameters for ice sheet, sea ice, and ocean**
 - **maximize repeatability of mean elevation over time**
 - **minimize atmospheric effect on the derived elevation**
 - **one set of parameters for land**
 - **preserve all peaks inherently present**
 - **calculate elevations for all surfaces present in footprint**
 - **Algorithm will implement the prototyped methodology, but will also include other capabilities that have been proven to be beneficial in ice radar altimetry processing to allow for improvement.**

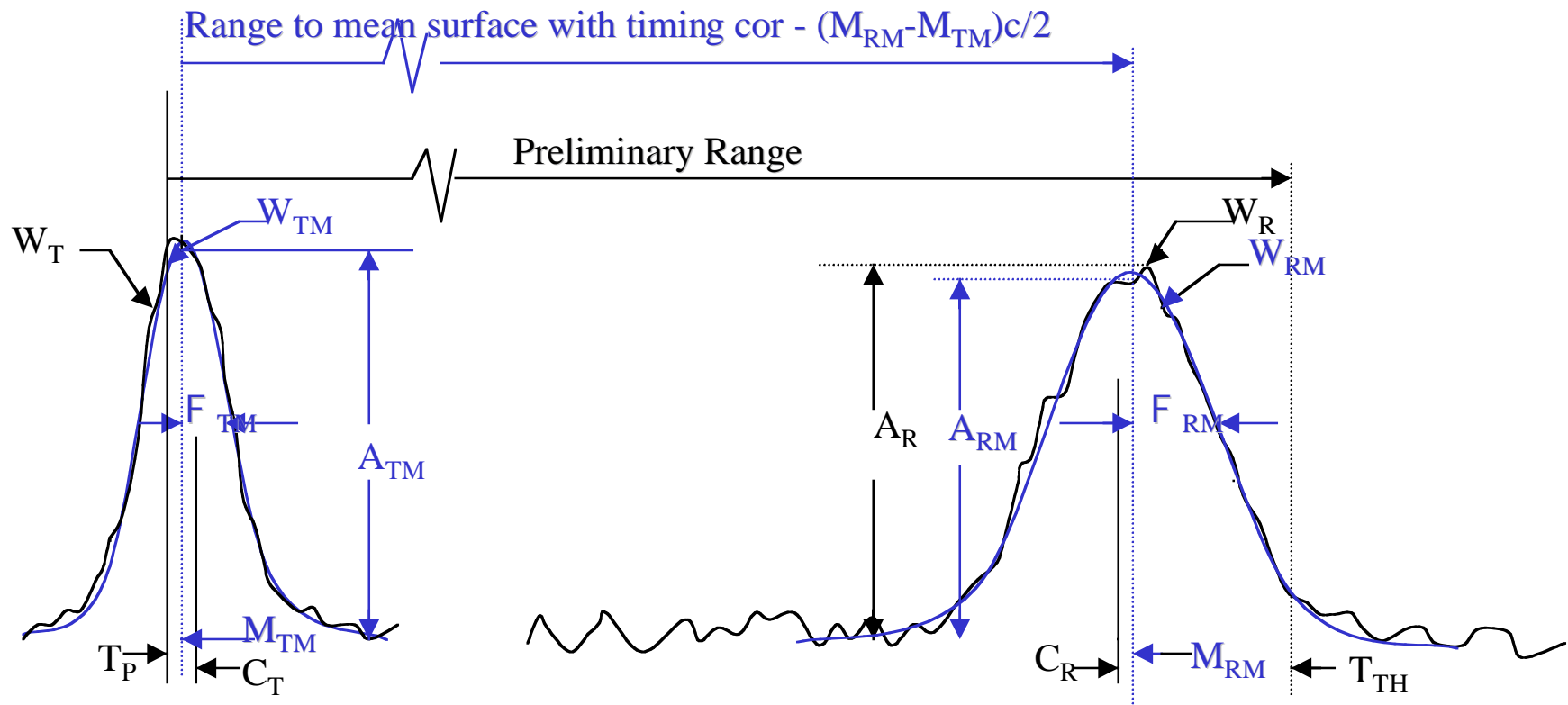
PRELIMINARY RANGE & RETURN SIGNAL CHARACTERIZATION



FITTING OF RECEIVED PULSE WAVEFORM

- Fit Received Pulse to Model
- Calculate A_{RM} , W_{RM} , M_{RM} , F_{RM}

$$w(t) = \varepsilon + \frac{6}{1} A_{RM} \exp - \frac{(t - M_{RM})^2}{2\sigma_{RM}^2}$$



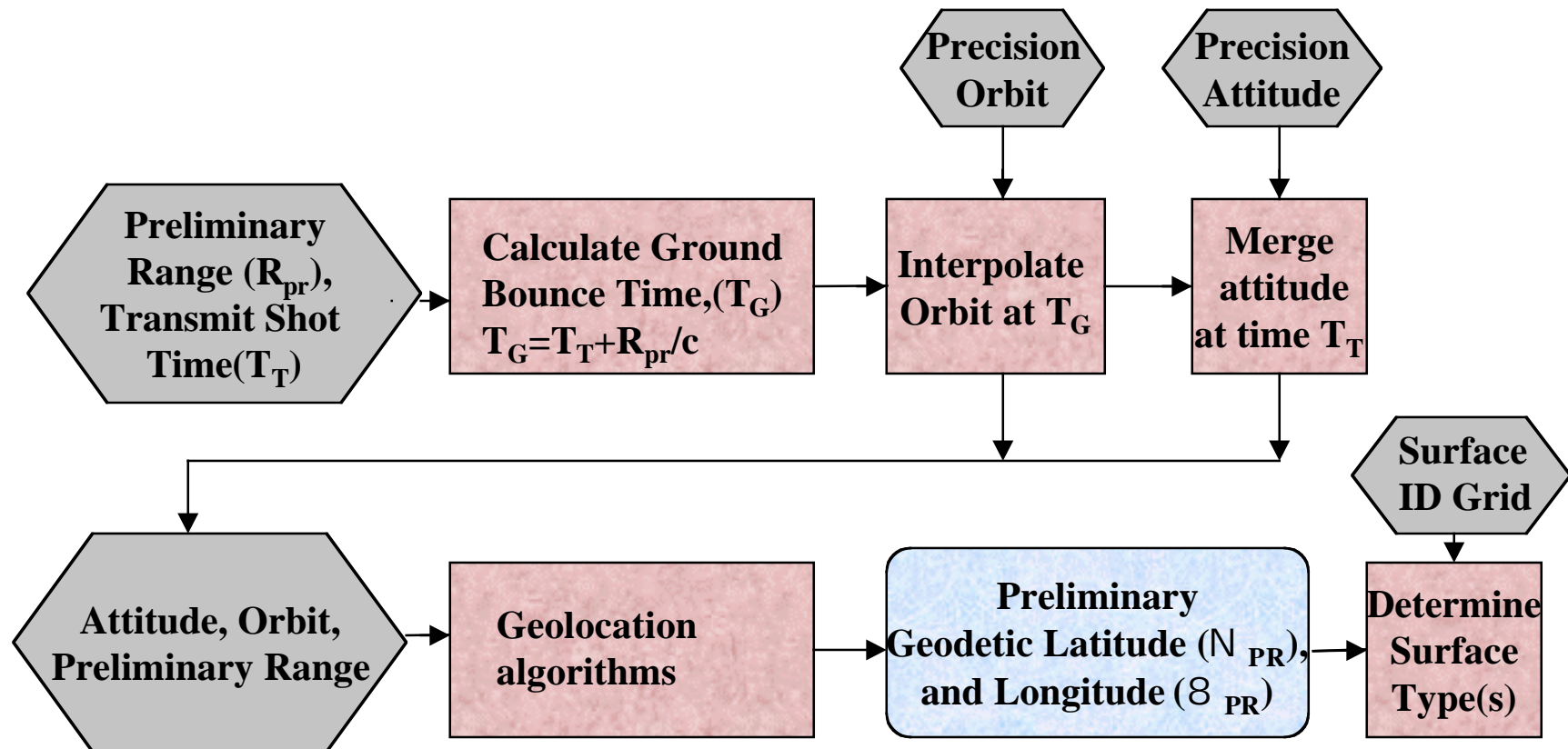
WAVEFORM ANALYSIS OUTPUT PRODUCT

GLA05 - level 1b global waveform product containing all parameters calculated from the waveform at the full data rate

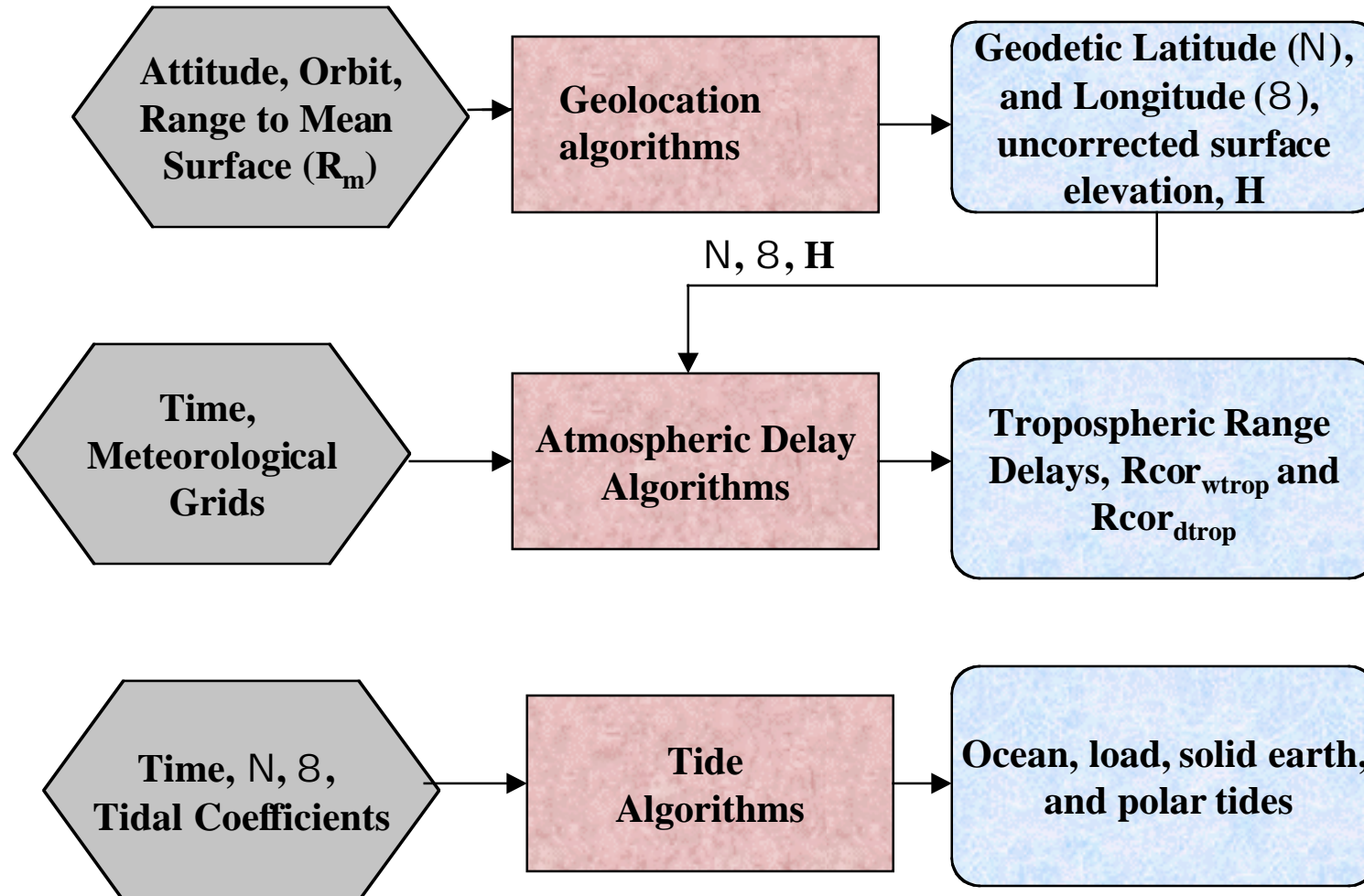
- UTC time
- Laser off-nadir pointing vector
- Spacecraft Orbit vector
- Reference Range
- Preliminary range increment
- Range increments to first and last threshold crossings
- Preliminary geodetic location
- Received Waveform fit (output for other and/or land surf type)
 - Number of Peaks
 - Gaussian parameters
 - Errors on Gaussian parameters
 - Goodness of fit (P^2)

- Saturation flags and amounts
- Transmit and Receiver Gains
- Transmit and Receiver optical to detector volt efficiency
- Transmit and Received Pulse Characteristics
 - Area under pulse
 - Peak amplitude
 - Centroid and skewness
 - Gaussian fit parameters
- Ranking of peaks for multi-peak receiver pulse Gaussian fit
- Surface type ID(s)

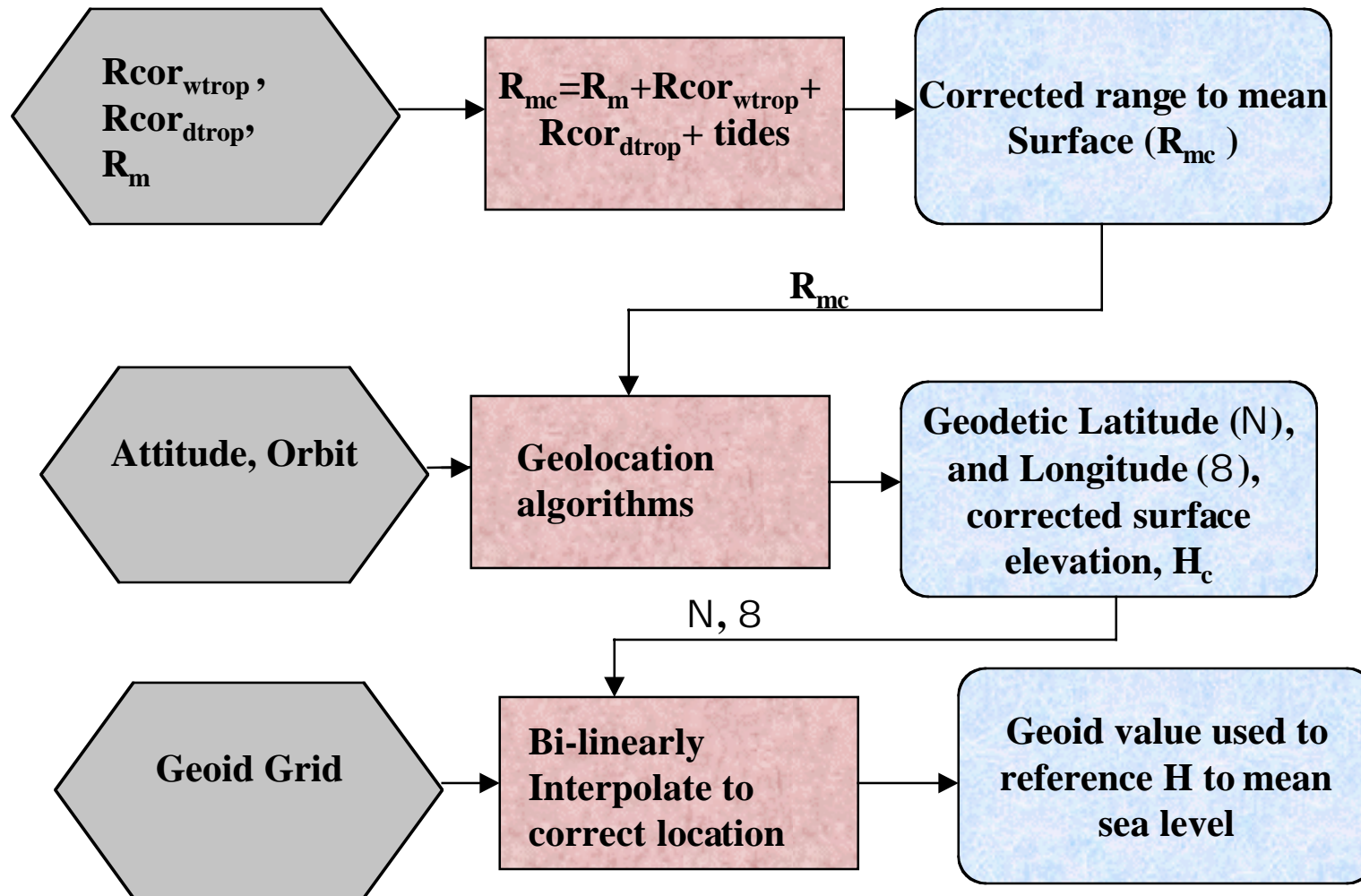
GEOLOCATION OF FOOTPRINT & DETERMINATION OF SURFACE TYPE(S)



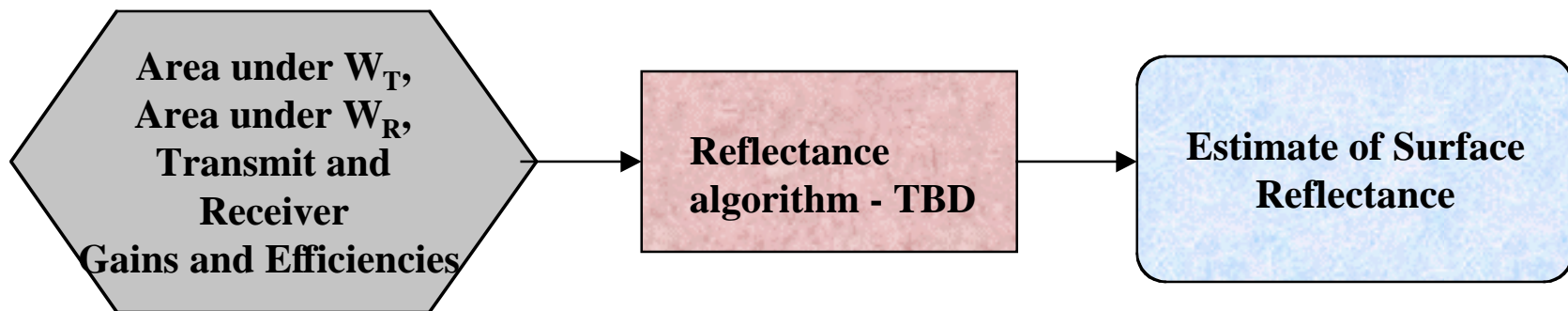
RANGE CORRECTIONS



CORRECT RANGE AND CALCULATE PRECISE GEOLOCATION



REFLECTANCE CALCULATIONS



LEVEL 1B - GLA06 – GLOBAL ELEVATION PRODUCT

- **Corrected preliminary surface elevation**
- **Footprint location**
- **Elevation distribution within footprint**
- **Laser off-nadir pointing**
- **Spacecraft orbit**
- **Corrected Range**
- **Atmospheric delay**
- **Tidal Values**
- **Increments to calculate mean surface elevations**
- **Geoid**
- **Elevation quality flags**
- **Waveform quality flags**
- **Atmospheric condition flags**
- **Reflectance estimate**

LEVEL 2 - GLA12-15 REGIONAL PRODUCTS FOR ICE SHEET, SEA ICE, LAND, AND OCEAN

- **Corrected surface elevation**
- **Footprint location**
- **Elevation distribution within footprint**
- **Laser off-nadir pointing**
- **Spacecraft orbit**
- **Corrected Range**
- **Atmospheric delay**
- **Tidal Values**
- **Geoid**
- **Elevation quality flags**
- **Waveform quality flags**
- **Atmospheric condition flags**
- **Reflectance estimate**
- **Region-specific output**

WAVEFORM AND ELEVATION PROCESSING

Practical Considerations

- **Programmer/Procedural Considerations**
 - The program must be able to process data from all surface types or to select and process only ice sheet and sea ice data.
 - Each algorithm should be programmed modularly so alterations to an individual algorithm will only affect that module.
- **Quality Control and Diagnostics**
 - Summary information on the processing must be provided to allow the science team to assess the quality of the data and related products.

WAVEFORM ANALYSIS

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WAVEFORM SUBSYSTEM

- **Requirements**
 - **Implement GLAS ATBD “Derivation of Range and Range Distributions From Laser Pulse Waveform Analysis for Surface Elevations, Roughness, Slope, and Vegetation Heights”, version 2.0.**

WAVEFORM SUBSYSTEM

- **Inputs**

- **GLA01**

- | | |
|-------------------------|---------------------------------------|
| • r_wf_trans | Transmitted Pulse |
| • r_wf_rec | Received Waveform |
| • d_compression | compression ratios for Rec WF |
| • i_ndxCompChg | Gate index where comp. changes |
| • r_tel_sat | Telemetered saturation |
| • d_FiltWidthMin | Min filter width |
| • d_FilterOb | Observed filter width |
| • d_TimeGate1Tr | Transmitted pulse gate-1 time |
| • d_TimeGate1Rec | Rec WF gate-1 time |
| • d.UTC1stPTime | UTC time of 1st shot of frame |
| • d_dShotTime | delta shot times |
| • d_bgNoiseOb | Observed background noise |
| • d_sDevNsOb | Std dev of d_bgNoiseOb |

WAVEFORM SUBSYSTEM

- **Data passed through**
 - **telemetered noise level**
 - **received pulse gain**
 - **received energy**
 - **transmitted energy**
 - **transmitted gain**
- **Ancillary Data**
 - **waveform characterization and functional fit parameters**
 - **precision orbit data**
 - **precision attitude data**
 - **surface identifier grid**

WAVEFORM SUBSYSTEM

- **Outputs**
 - **GLA05 parameters**
 - **UTC time of transmitted pulse**
 - **Range from peak of transmitted pulse to last telemetered gate (d_refRng)**
 - **threshold retracker offset**
 - **max amplitude of smoothed WF**
 - **POD position vector**
 - **PAD pointing vector**

WAVEFORM SUBSYSTEM

- **Outputs**
 - **GLA05 parameters**
 - **Uncorrected Geodetic latitude & longitude**
 - **Uncorrected Surface Elevation**
 - **surface region flags (land, ocean, ice sheet, sea ice)**
 - **telemetered noise level**
 - **received pulse gain**
 - **received energy**
 - **transmitted energy**
 - **percent of signal saturated from signal begin to end**
 - **transmitted gain**

WAVEFORM SUBSYSTEM

- **Outputs**
 - **GLA05 parameters - two values (land & other-than land)**
 - **kurtosis of raw WF from signal begin to end**
 - **skewness of raw WF from signal begin to end**
 - **initial number of peaks found during fit**
 - **gaussian fit noise level**
 - **amplitude of gaussian fit peaks**
 - **sigma of each gaussian fit peak**
 - **position of each gaussian fit peak**
 - **standard deviation from the covariance matrix for each fit parameter**

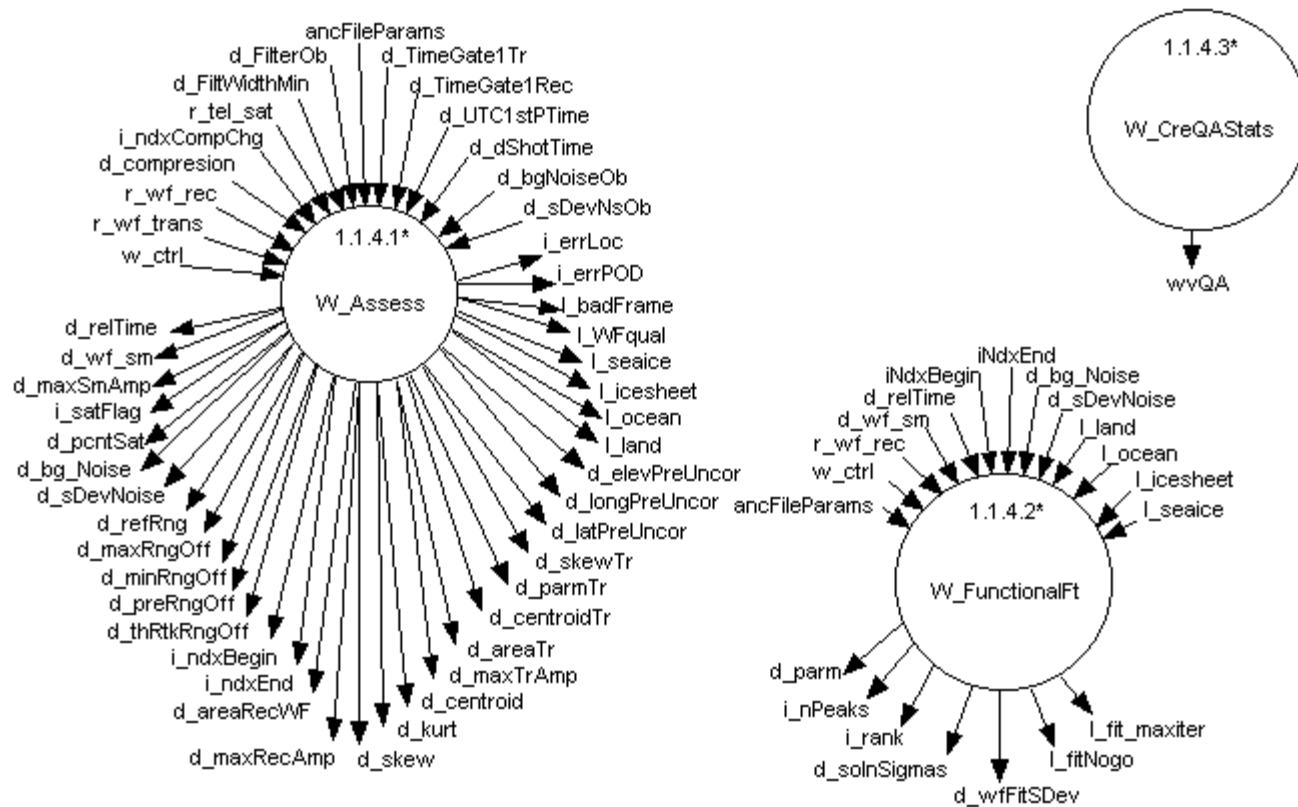
WAVEFORM SUBSYSTEM

- **Outputs**
 - **GLA05 parameters - two values (land & other-than land)**
 - **flags indicating successful fit & fit convergence criteria met**
 - **chi squared of functional fit**
 - **ranks of each fit peak**
 - **area under raw WF from signal begin to end**
 - **time offset from d_refRng to centroid of raw WF**
 - **time offset from d_refRng to signal begin**
 - **time offset from d_refRng to signal end**
 - **saturation flag**

WAVEFORM SUBSYSTEM

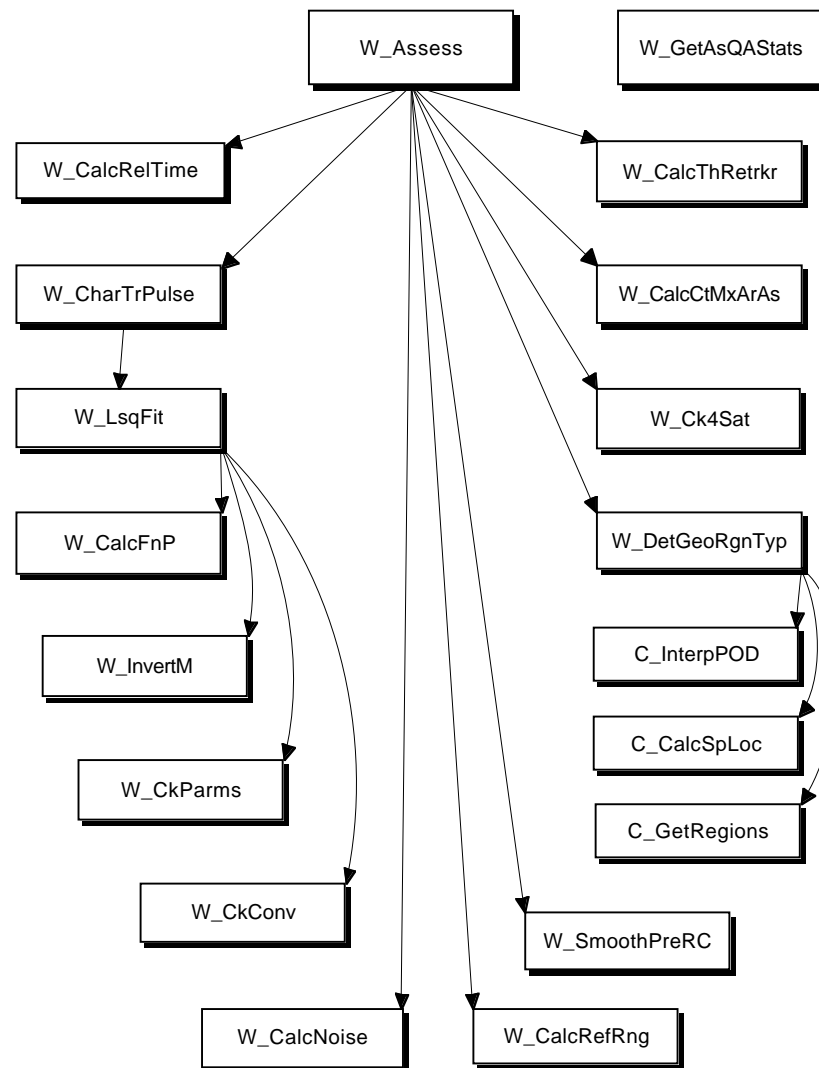
- **Outputs**
 - **GLA05 parameters - transmitted pulse characteristics**
 - **amplitude of gaussian fit**
 - **sigma of gaussian fit**
 - **location of gaussian peak**
 - **skewness of raw transmitted pulse**
 - **centroid of raw transmitted pulse**
 - **area under the raw transmitted pulse**
 - **max amplitude of raw transmitted pulse**

WAVEFORM SUBSYSTEM

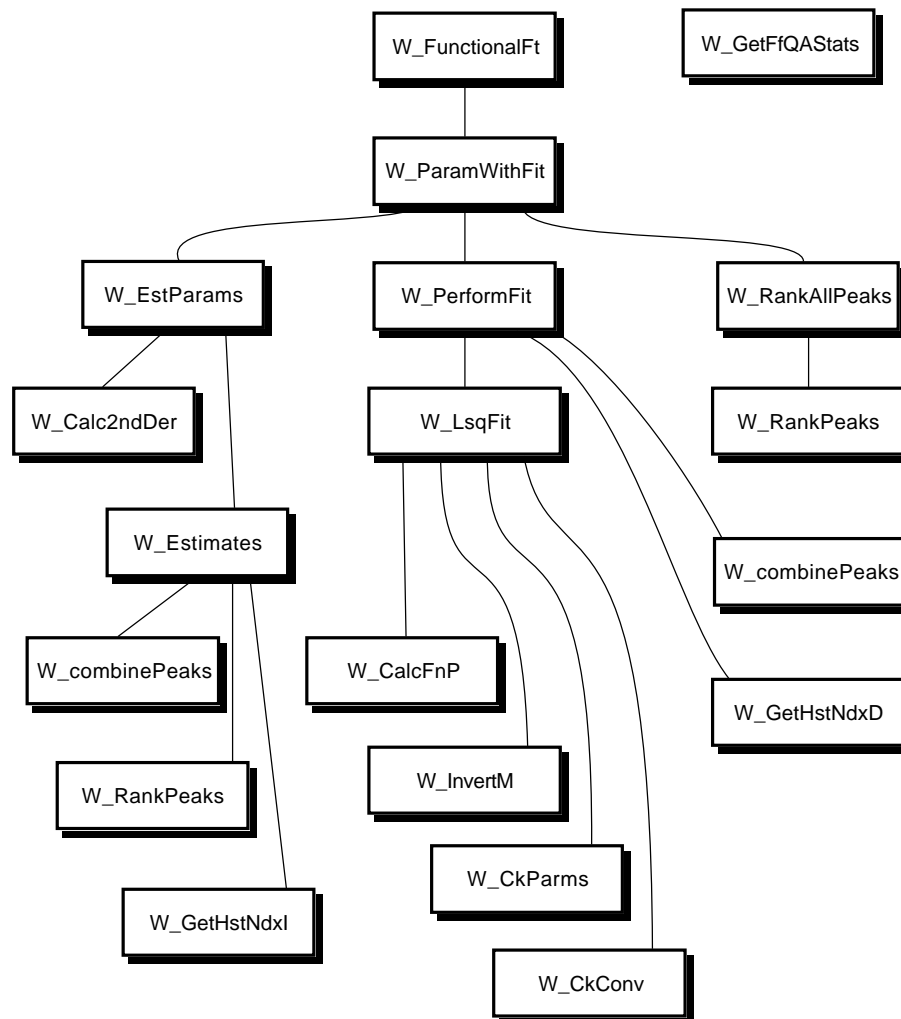


Level 1B Waveforms

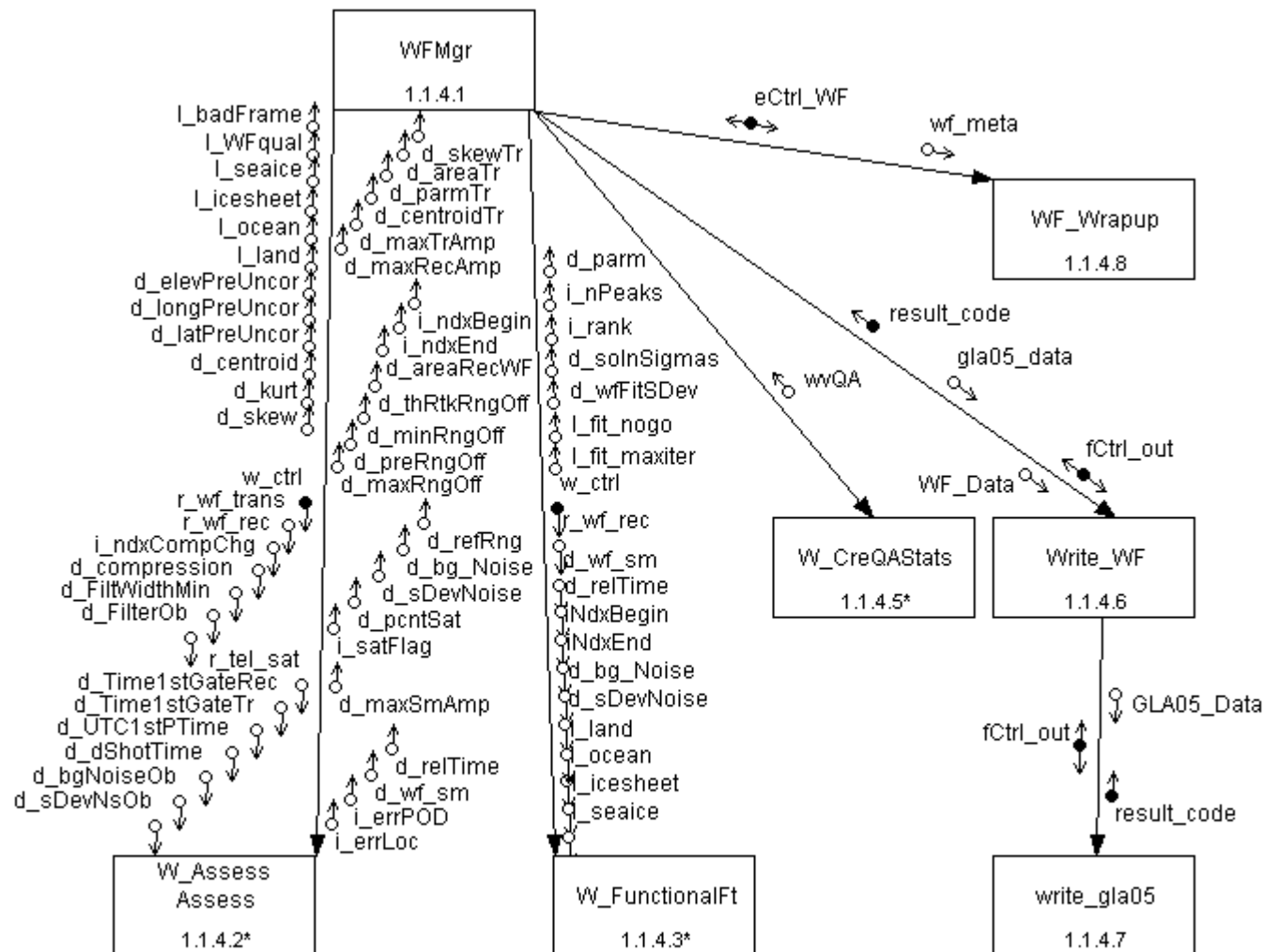
WAVEFORM SUBSYSTEM



WAVEFORM SUBSYSTEM

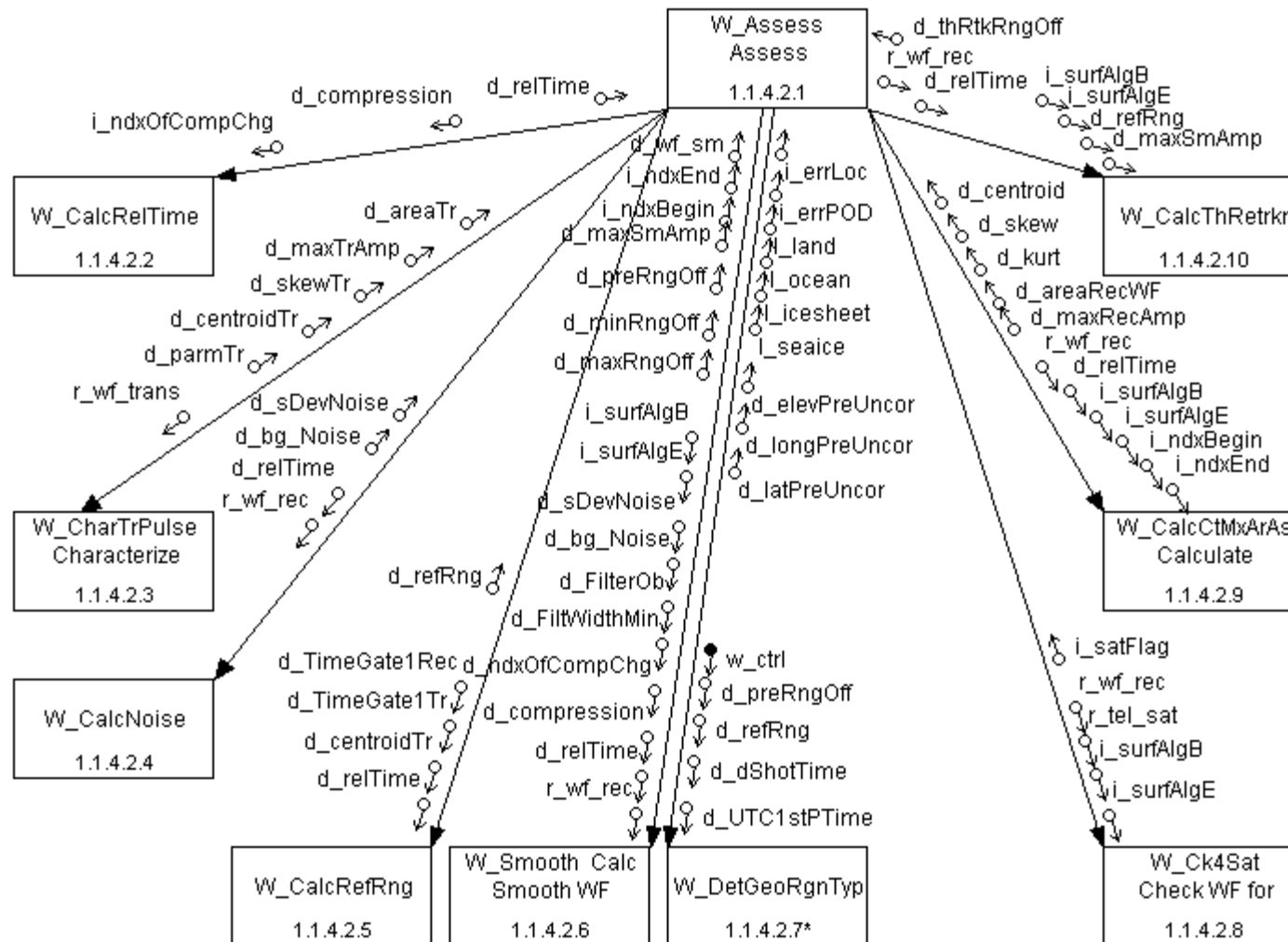


Waveform Subsystem



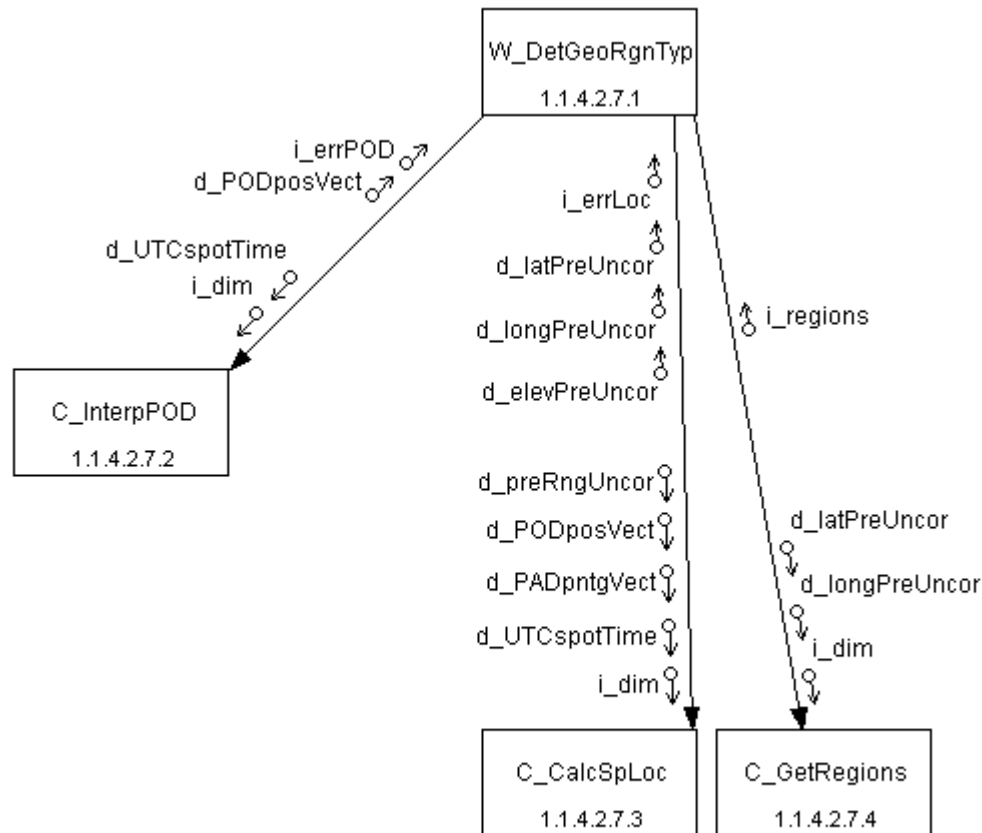
Level 1B Waveforms Structure Chart

WAVEFORM SUBSYSTEM



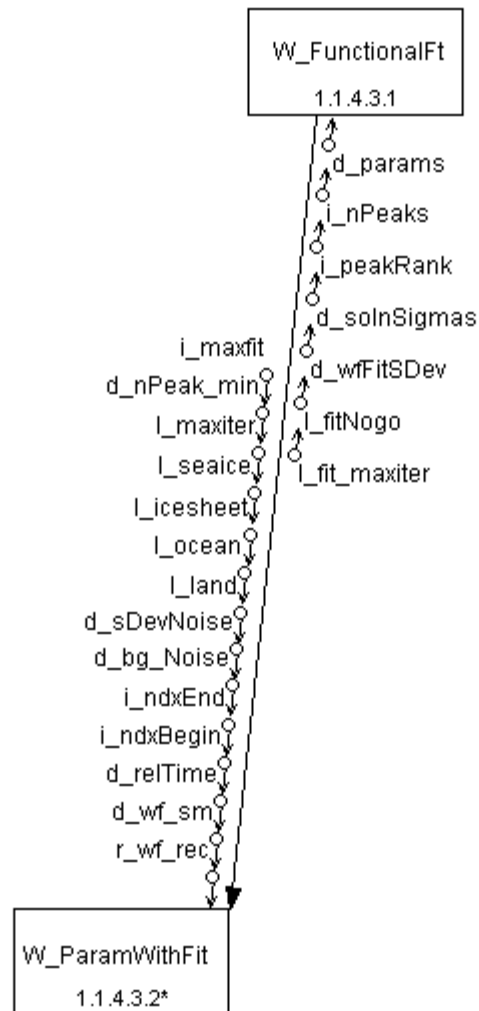
Assess Waveforms & Calc Std Range Offset Structure Chart

WAVEFORM SUBSYSTEM



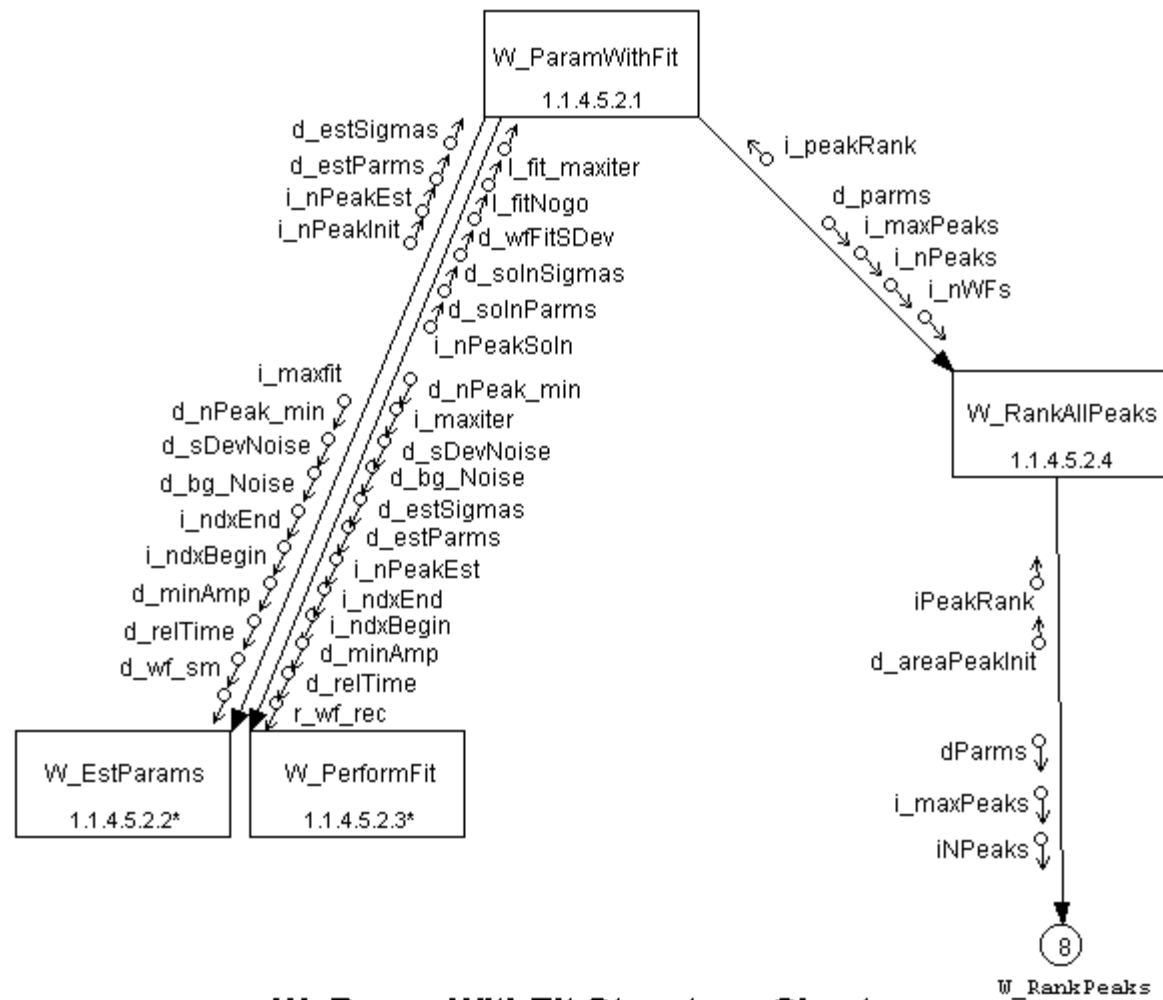
W_DetGeoRgnTyp Structure Chart

WAVEFORM SUBSYSTEM



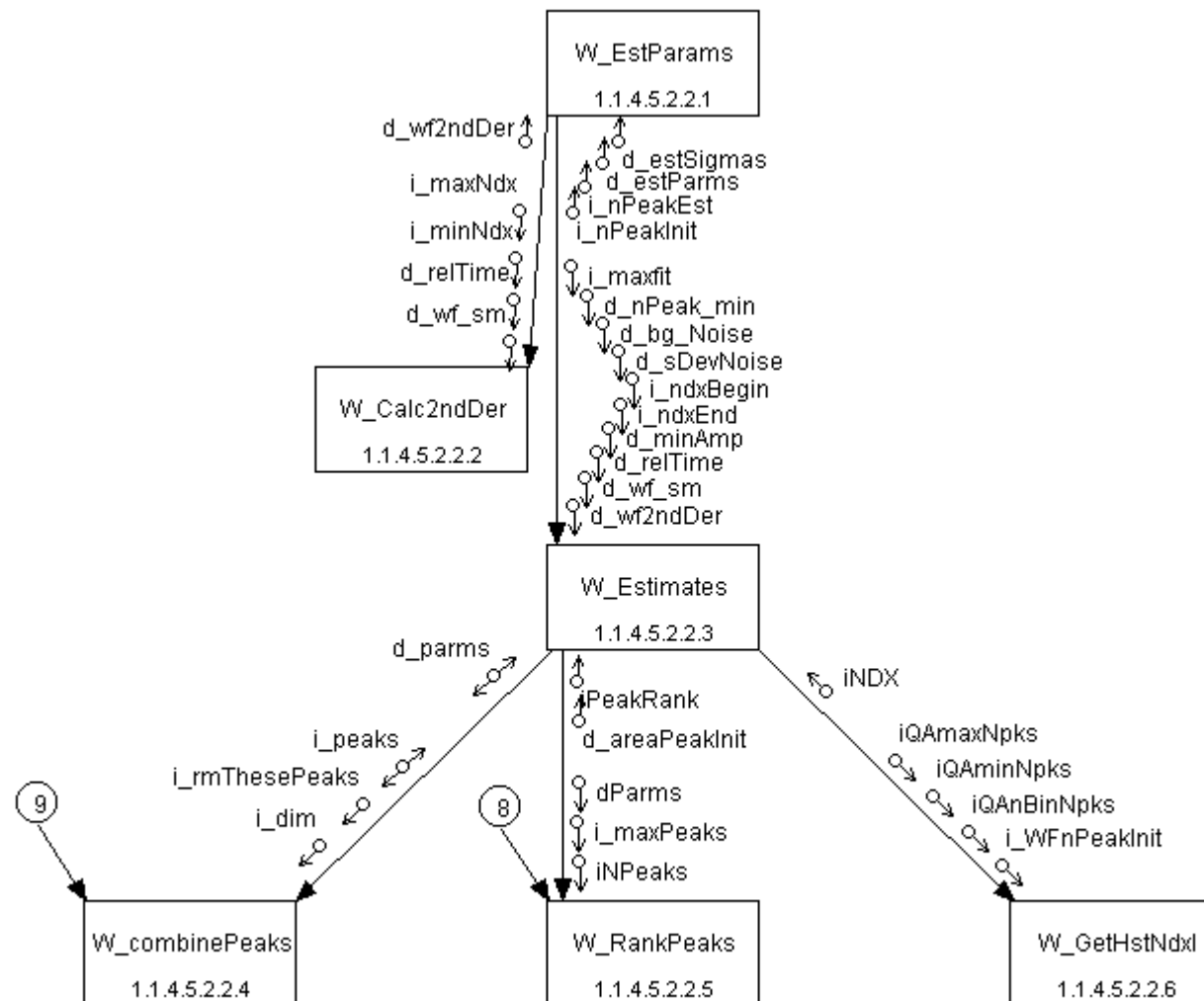
Calculate Other WF Characteristics Structure Chart

WAVEFORM SUBSYSTEM



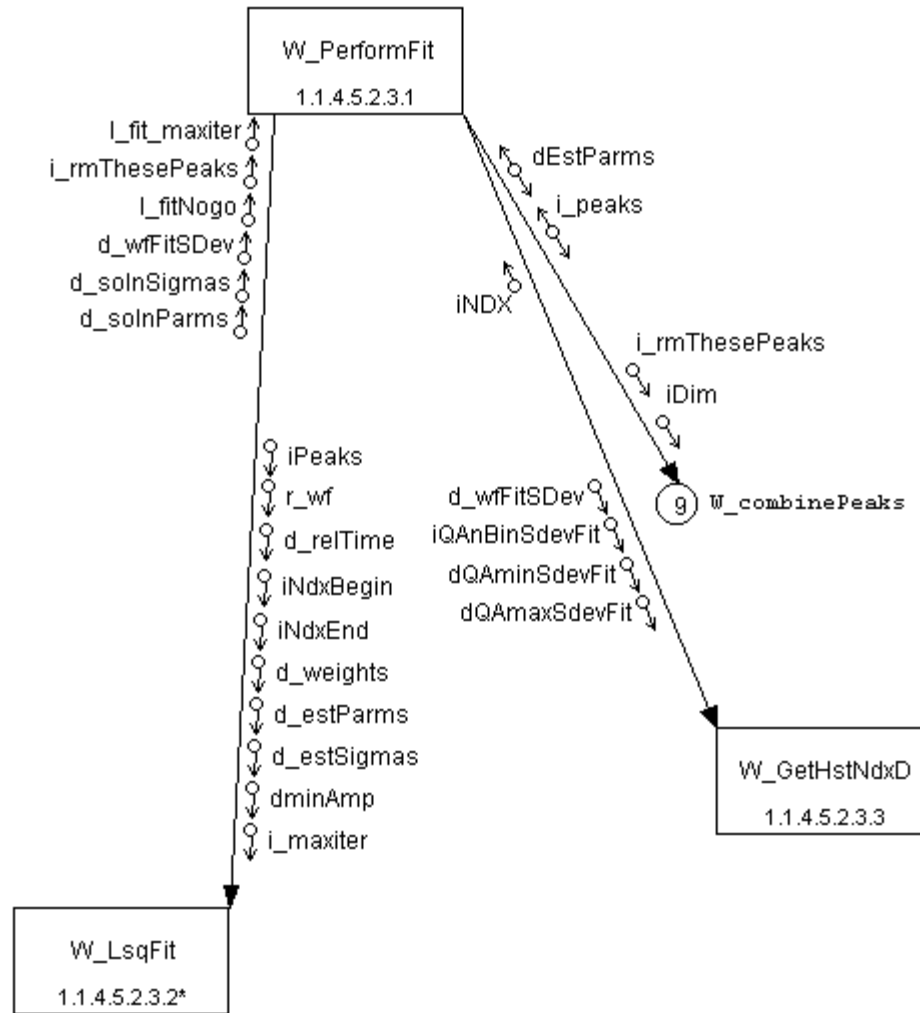
W_ParamWithFit Structure Chart

WAVEFORM SUBSYSTEM



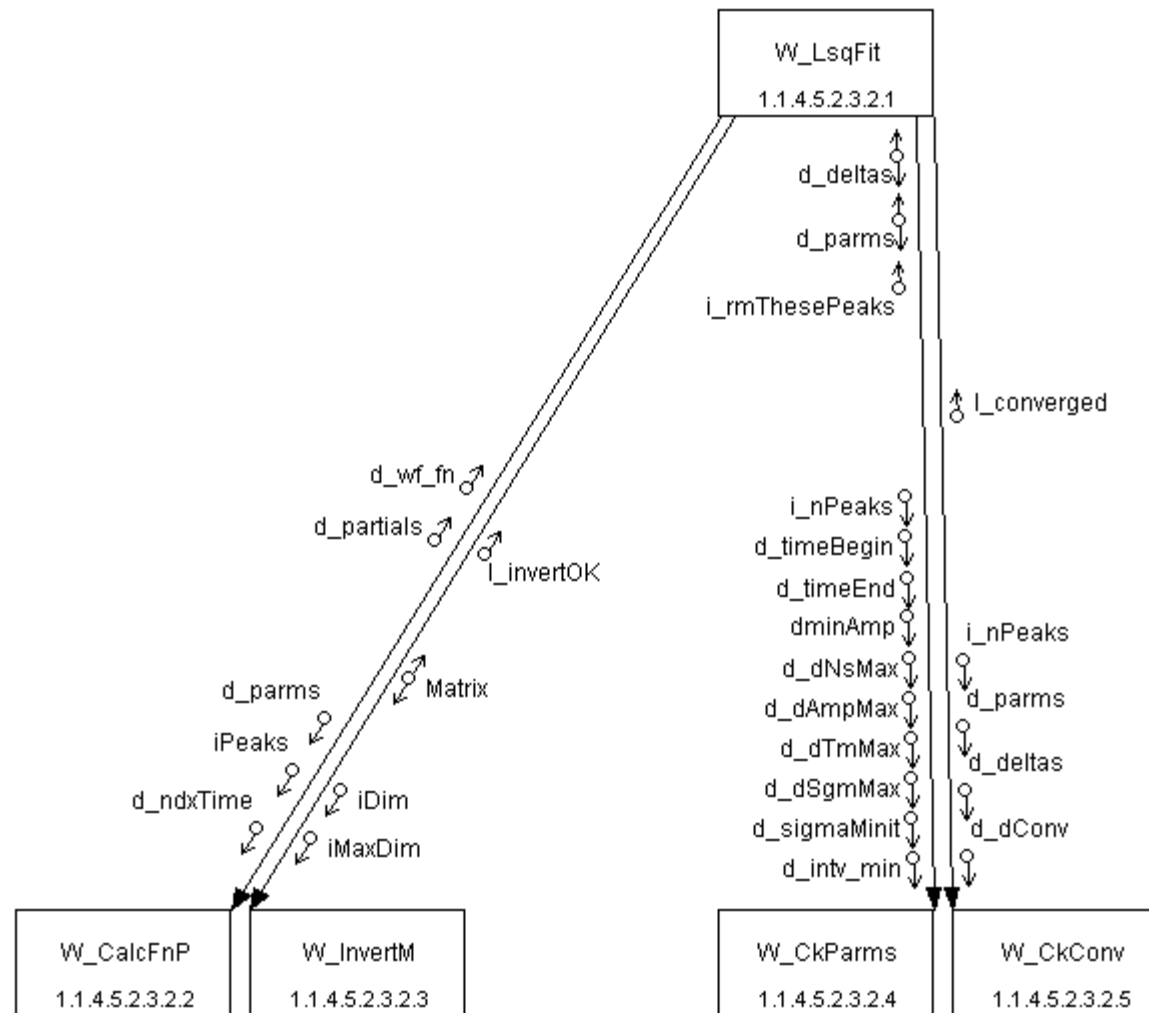
W_EstParams Structure Chart

WAVEFORM SUBSYSTEM



W_PerformFit Structure Chart

WAVEFORM SUBSYSTEM



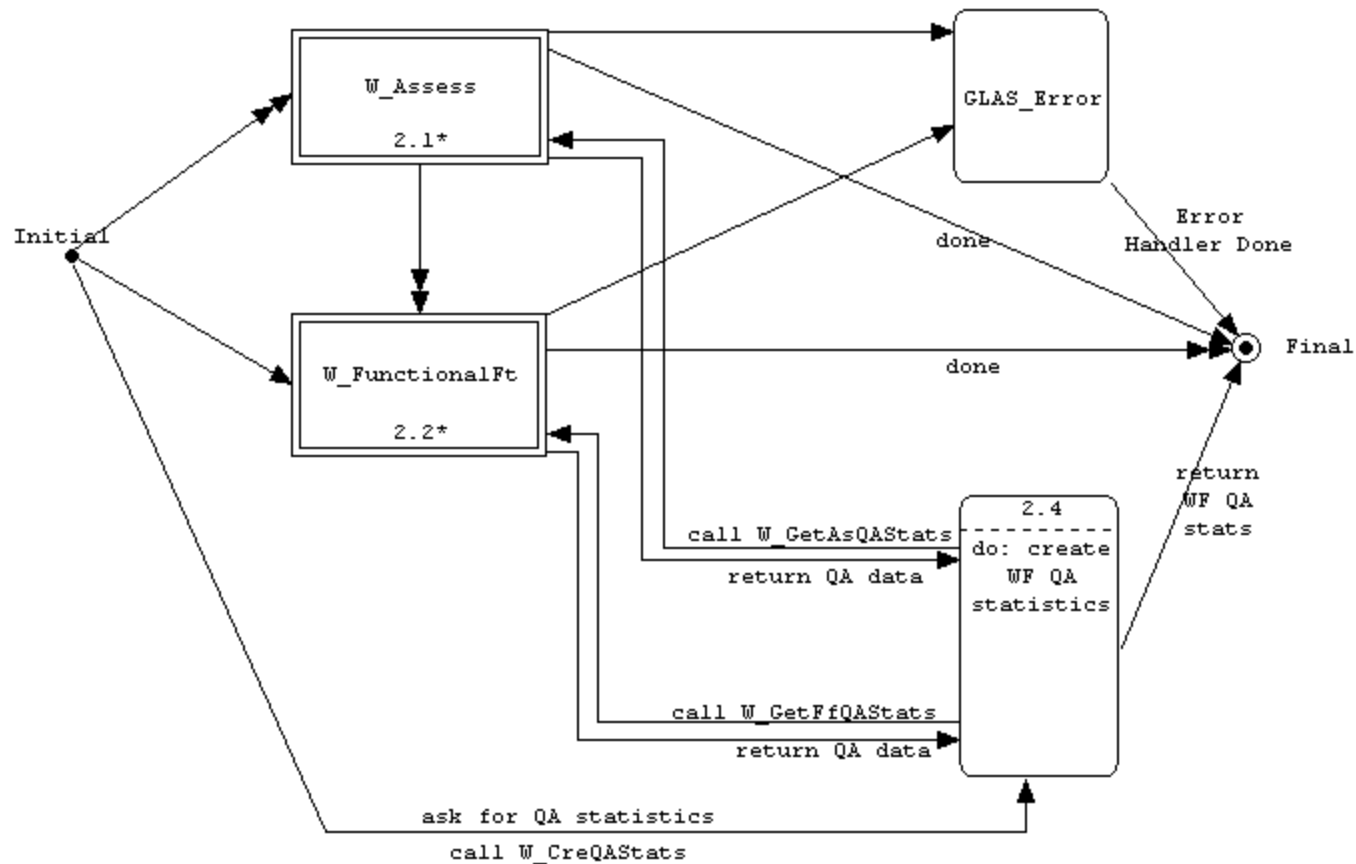
W_LsqFit Structure Chart

WAVEFORM SUBSYSTEM

If these variables change:	1	2	3	4
land algorithm parameters	x			
non-land algorithm parameters		x		
orbit (POD)			x	
attitude (PAD)				x
Then these actions are taken:				
W_Assess / W_SmoothPreRC	x	x		
W_Assess / W_Ck4Sat	x	x		
W_Assess / W_CalcCtMxArAs	x	x		
W_Assess / W_DetGeoRgnTyp / C_InterpPOD			x	
W_Assess / W_DetGeoRgnTyp / C_CalcSpLoc			x	x
Calculate Functional Fit (W_FunctionalFt)	x	x		

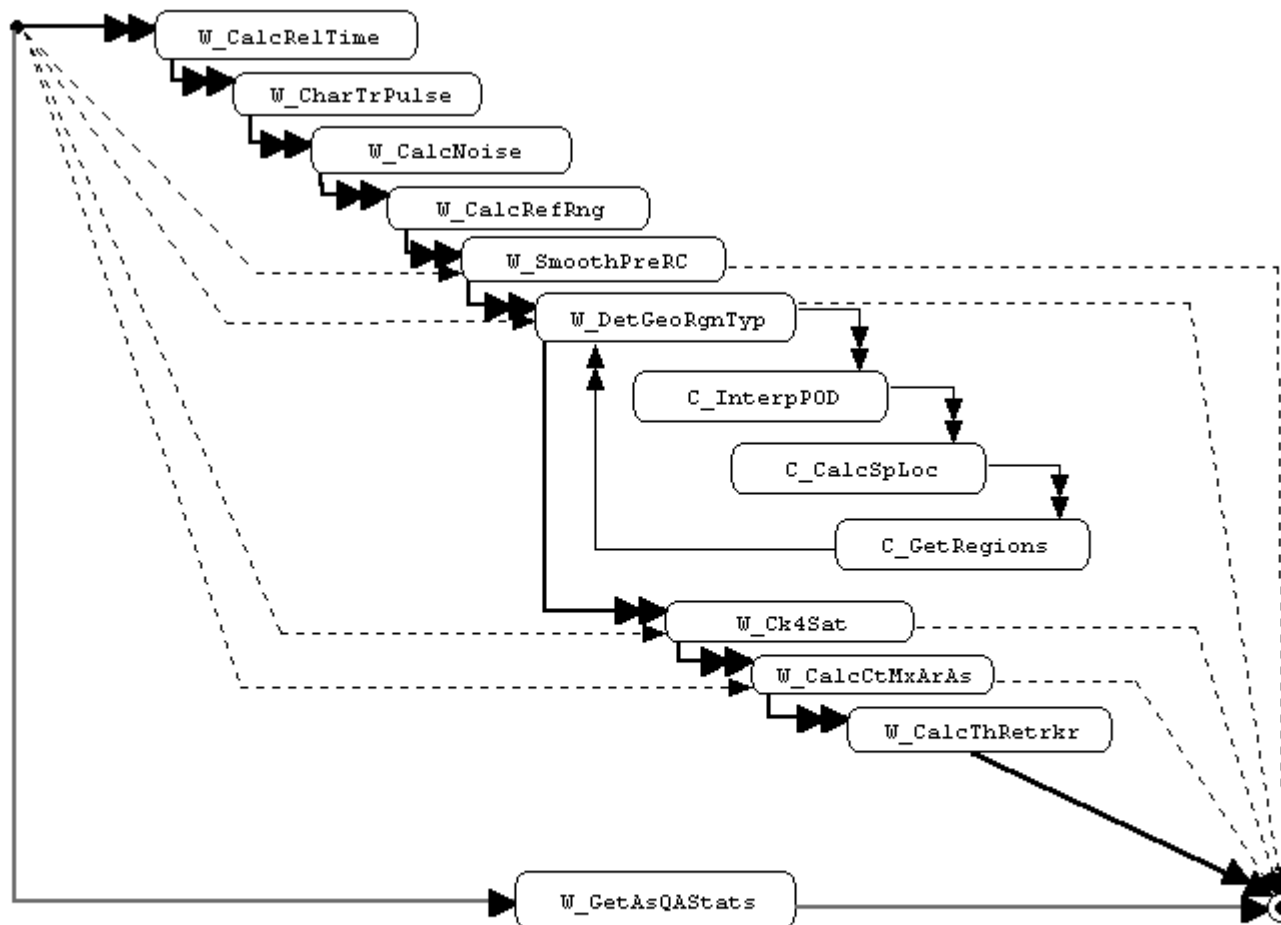
Reprocessing Decision Table

WAVEFORM SUBSYSTEM



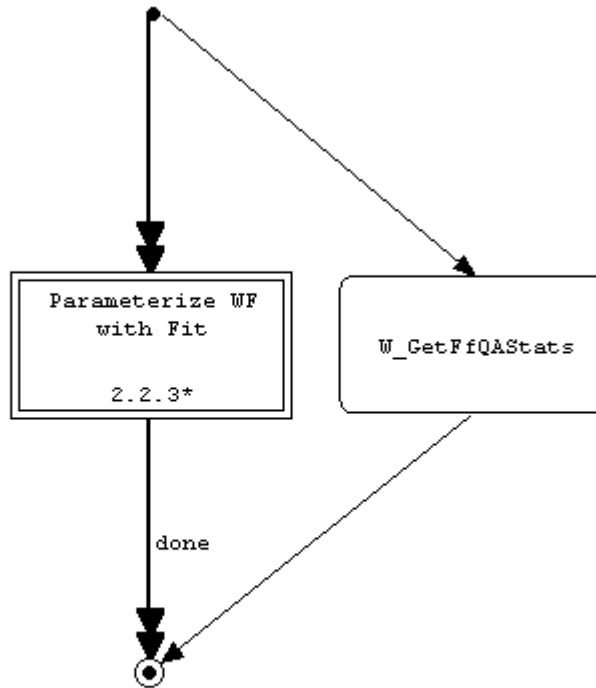
**Level 1B Waveforms
State Diagram**

WAVEFORM SUBSYSTEM



**Assess Waveforms & Calc Std Range Offset
State Diagram**

WAVEFORM SUBSYSTEM



W_FunctionalFt State Diagram

WAVEFORM SUBSYSTEM

- **Errors**
 - **Critical Errors (processing in W_DetGeoRgnTyp will stop and flags will be set)**
 - **critical error from C_InterpPOD**
 - **critical error from C_CalcSpLoc**
 - **Flags set for**
 - **No signal found**
 - **Singular matrix encountered during functional fit**
 - **Fit process exceeds max iterations without converging**
 - **Bad frame**

WAVEFORM SUBSYSTEM

- **QA Statistics (all WFs, land, ice-sheet)**
 - **WFs processed**
 - **percent with excess saturation**
 - **percent with no functional fit**
 - **percent no-fits due to singular matrices**
 - **percent with no signal**

WAVEFORM SUBSYSTEM

- **QA Statistics**
 - **histograms (all WFs, land, ice-sheet)**
 - **skewness**
 - **kurtosis**
 - **percent (saturation / real signal) from signal begin to end**
 - **number of iterations during fit**
 - **initial number of peaks found in smoothed WF**
 - **number of fit peaks**
 - **difference between centroids of raw WF & fit for last peak**
 - **standard deviation of fit to raw WF**

WAVEFORM SUBSYSTEM

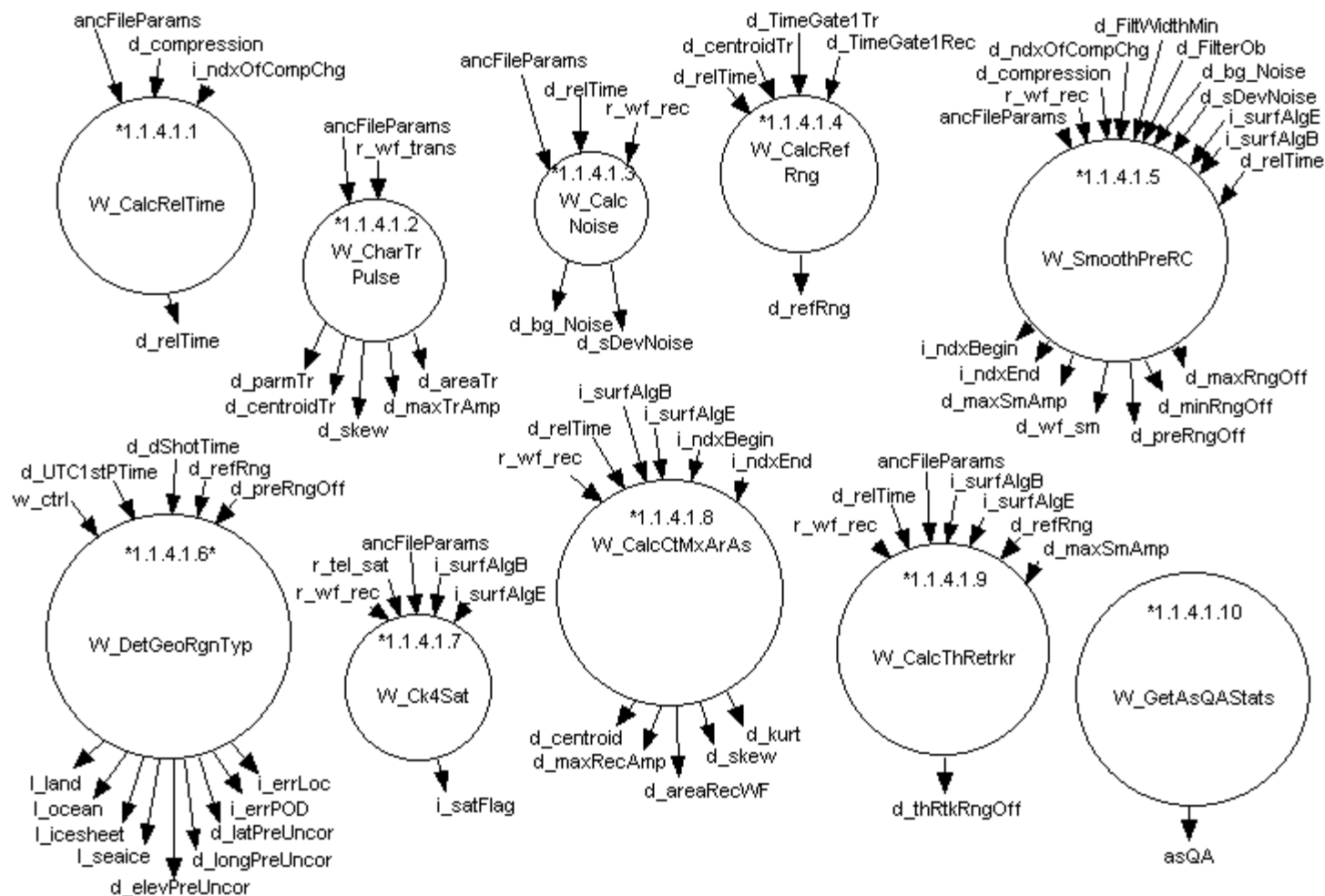
- **QA Statistics**
 - **histograms (all WFs & ocean)**
 - **time delay from raw WF centroid to last fit peak**
 - **time delay from signal begin to last fit peak**
 - **time delay from last fit peak to signal end**
 - **chi squared of fit**
 - **histograms (all WFs & sea-ice)**
 - **time delay from signal begin to raw WF centroid**
 - **time delay from raw WF centroid to signal end**

WAVEFORM SUBSYSTEM

- **Status**
 - **Waveform Functional Fit module**
 - coded & tested
 - currently experimenting with ancillary parameters
 - **Waveform Assessment**
 - coded
 - currently testing
 - **Waveform QA Statistics**
 - developed
 - W_FunctionalFit & W_Assess QA subroutines coded

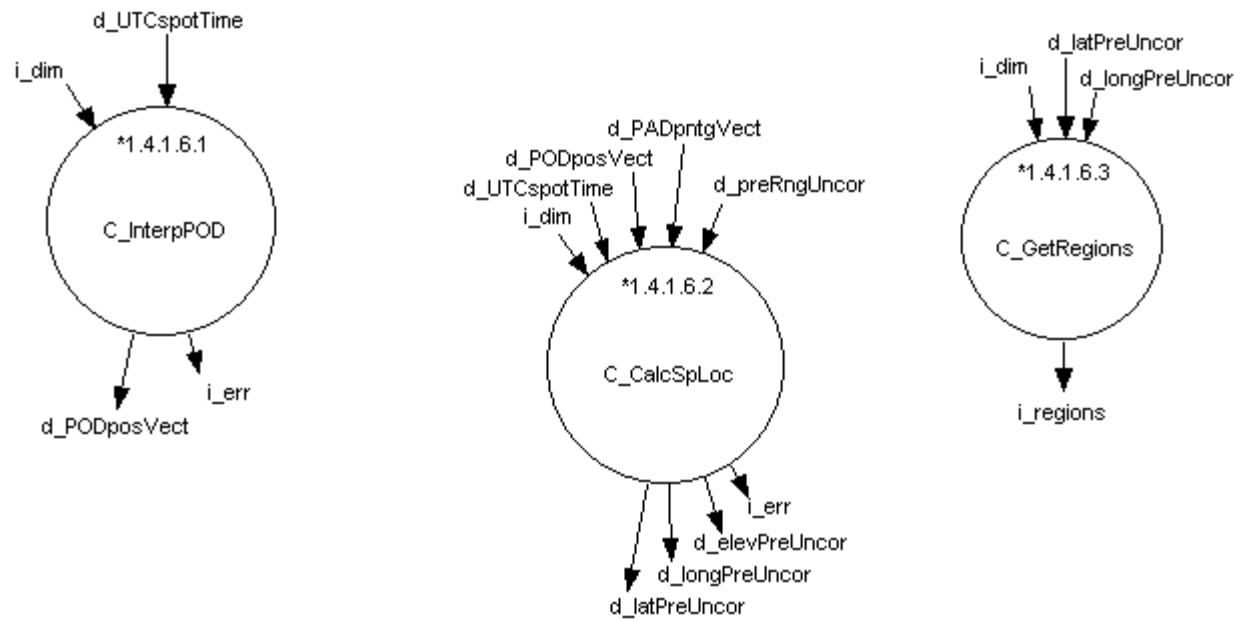
Supplemental Material

WAVEFORM SUBSYSTEM



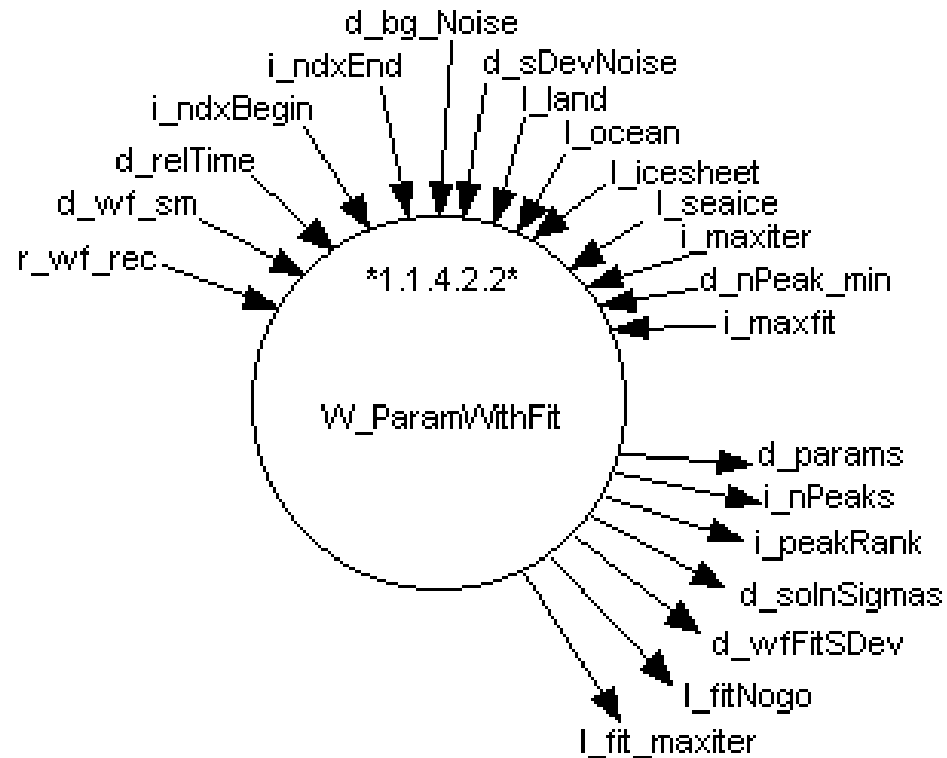
Assess Waveforms & Calc Std Range Offset

WAVEFORM SUBSYSTEM



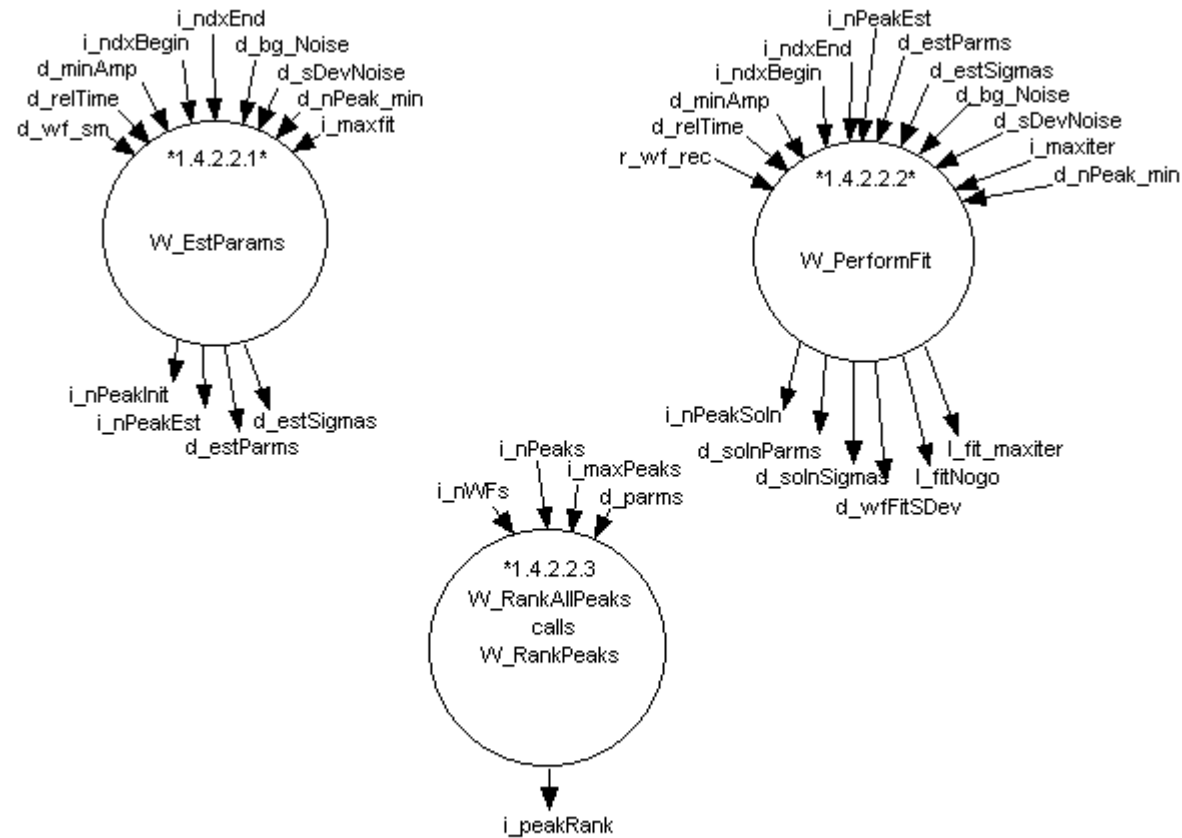
**W_DetGeoRgnTyp
DFD**

WAVEFORM SUBSYSTEM



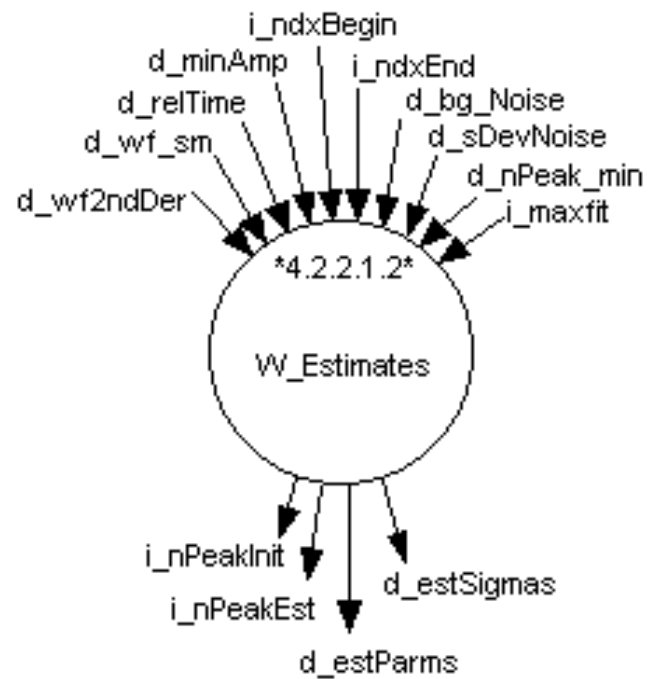
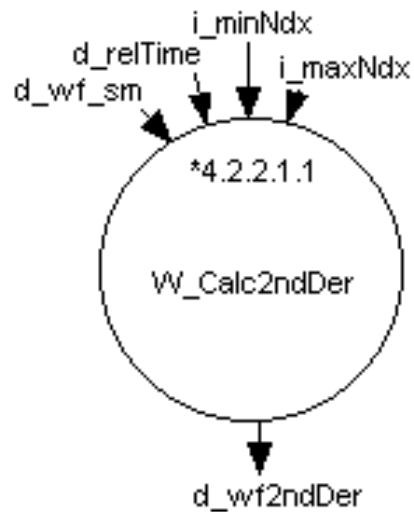
W_FunctionalFt

WAVEFORM SUBSYSTEM



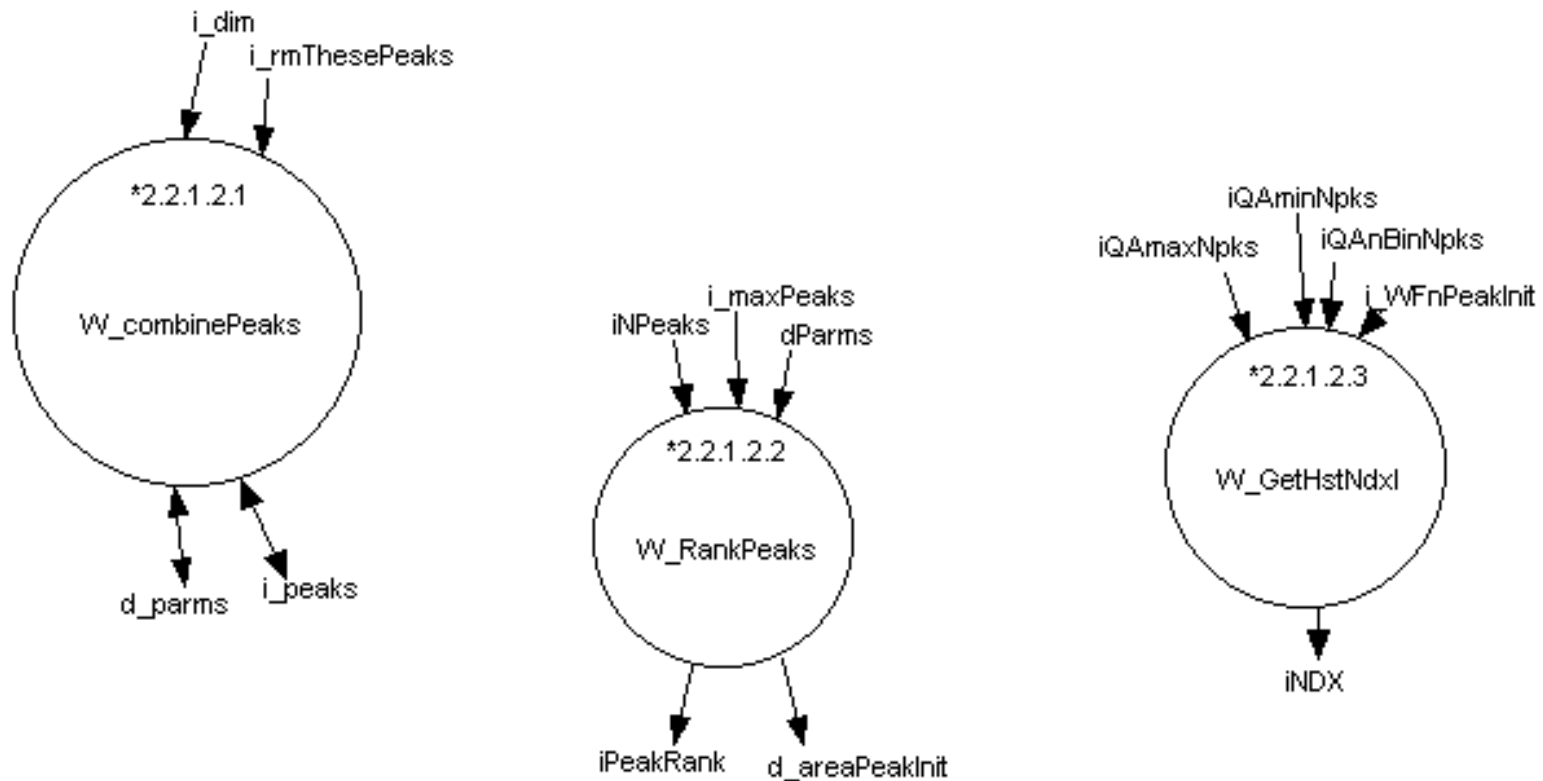
W_ParamWithFit

WAVEFORM SUBSYSTEM



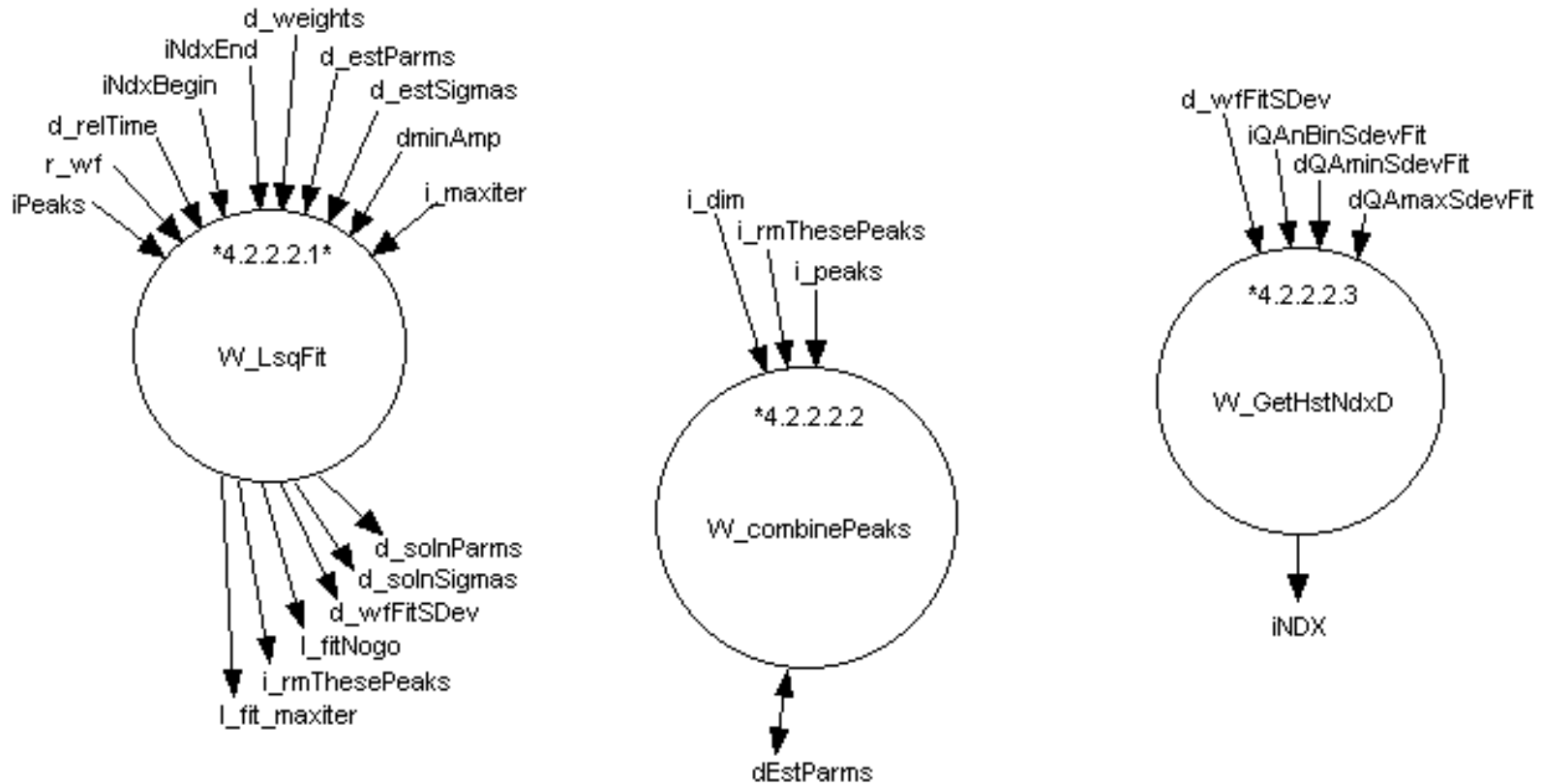
W_EstParams

WAVEFORM SUBSYSTEM



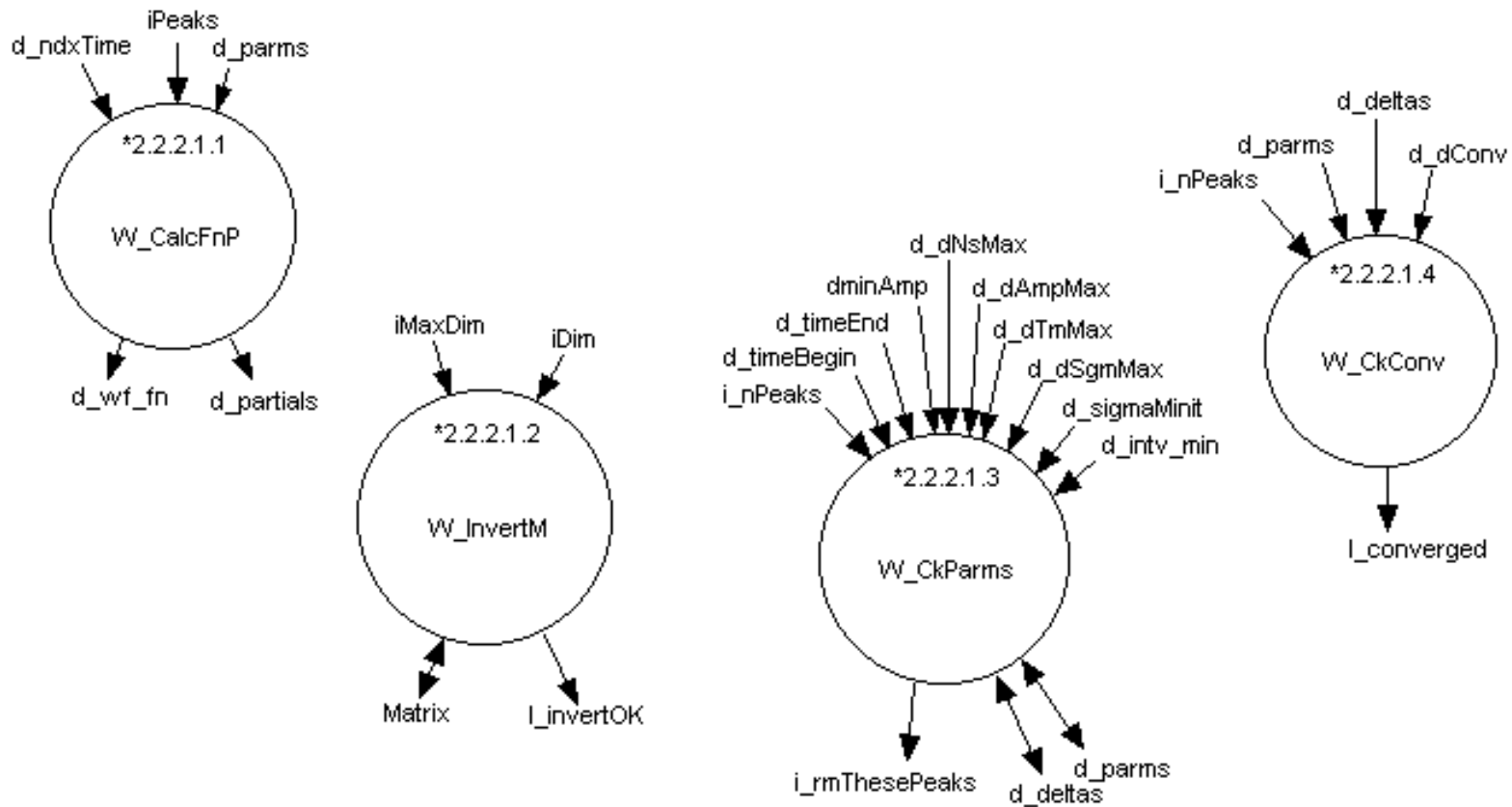
W_Estimates

WAVEFORM SUBSYSTEM



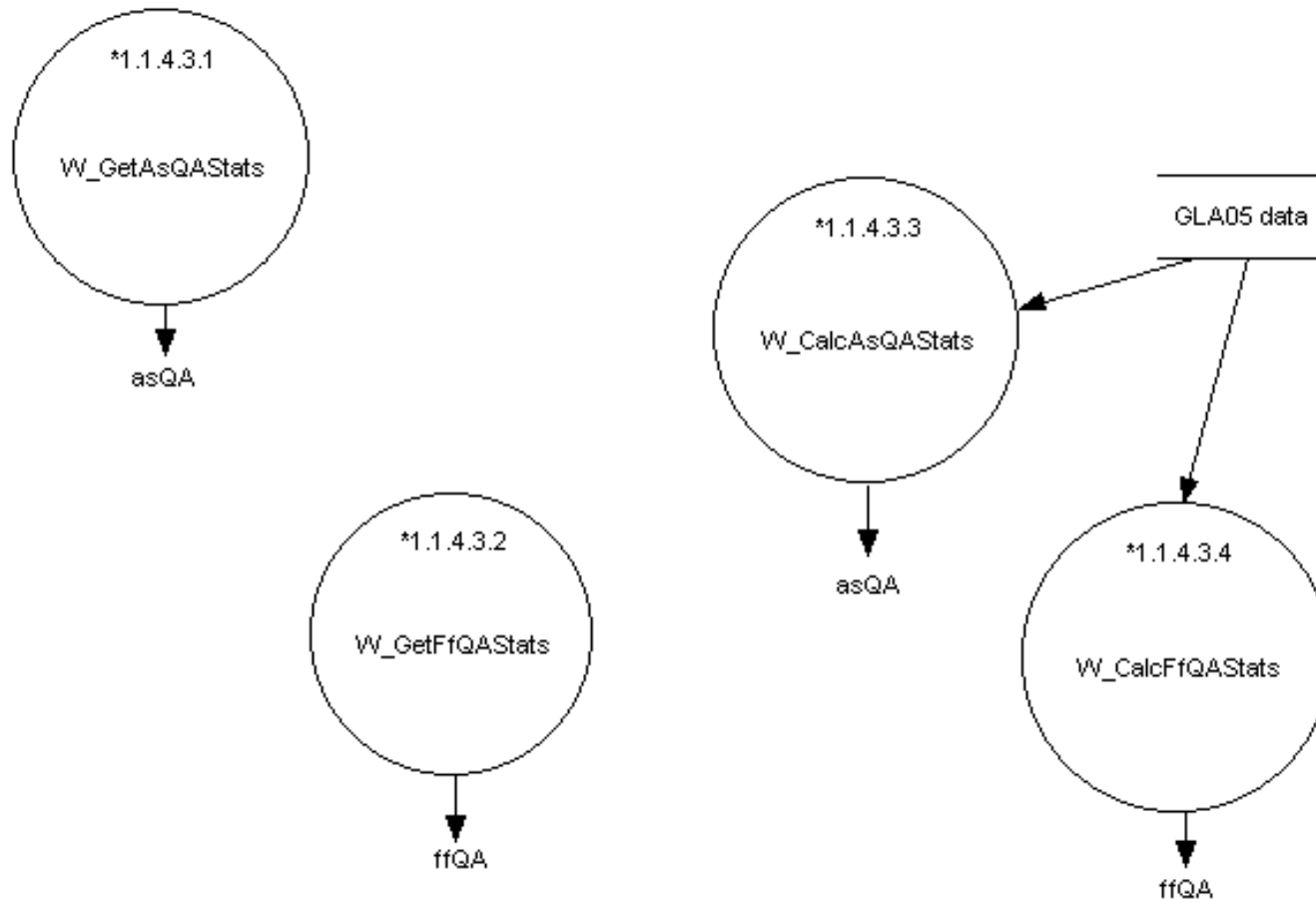
W_PerformFit

WAVEFORM SUBSYSTEM



W_LsqFit

WAVEFORM SUBSYSTEM



W_CreQAStats

ELEVATION ATBD SUMMARY/PRODUCTS

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ELEVATION SUBSYSTEM

- **Requirements**
 - **Implement Range Distribution/Waveforms
ATBD-GLAS-07 version 2.0**
 - **Implement Atmosphere Delay Correction
ATBD-GLAS-06 version 1.0**
 - **Implement Laser Footprint Location ATBD-GLAS-02
version 2.0**
 - **Implement Ocean Tidal Loading Corrections
ATBD-GLAS-05 version 2.0**

ELEVATION SUBSYSTEM

- **Requirements (continued)**
 - **Create level 1B elevation products (GLA06)**
 - **Elevation (40 Hz)**
 - **Corrections to the elevation**
 - **Reflectance**
 - **Slope**
 - **Data Quality information**
 - **Precision Orbit Georeference location, etc.**
 - **Create level 2 elevation products (GLA12-15)**
 - **Region Specific Elevation (40 Hz)**
 - **Corrections to the elevation**

ELEVATION SUBSYSTEM

- **Requirements (continued)**
 - **Reflectance**
 - **Slope**
 - **Data Quality information**
 - **Precision Orbit Georeference location, etc**
- **Create level 1B and 2 QA statistics**
 - **Histogram of corrections**

ELEVATION SUBSYSTEM

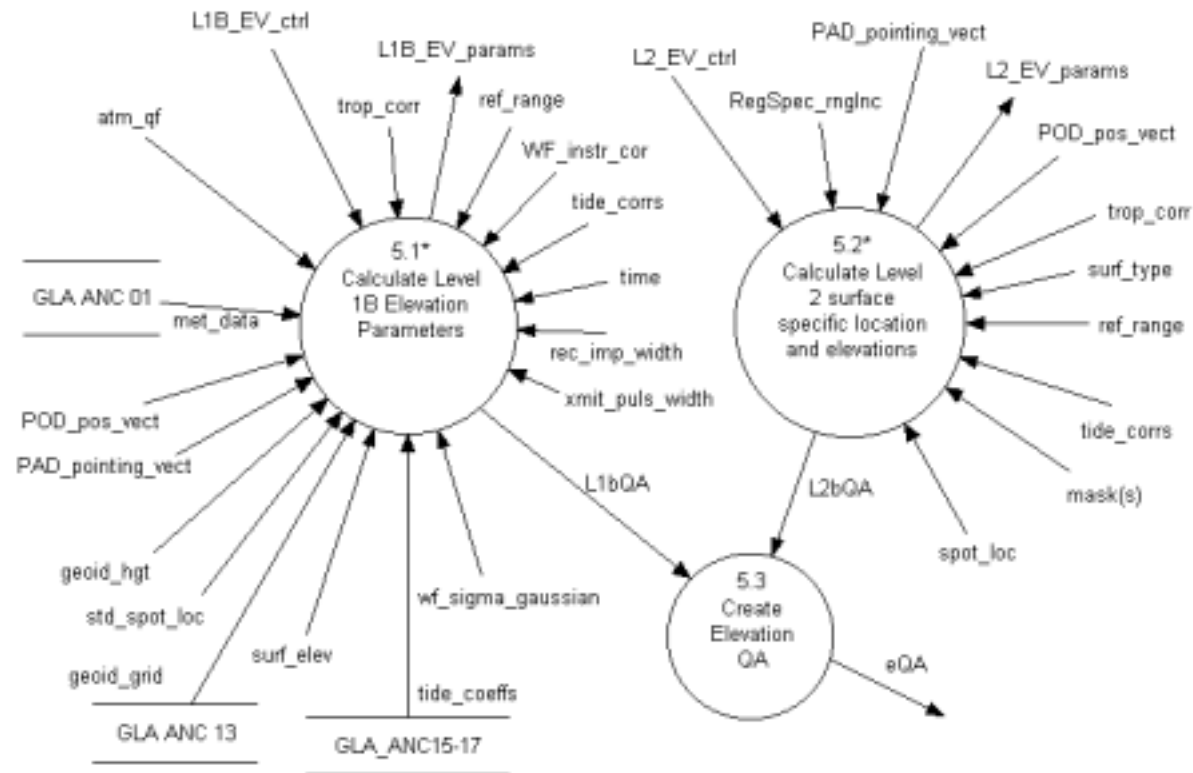
- **Level 1B and 2 Inputs**
 - **Met Data** (GLA ANC 01)
 - **Range**
 - **POD position vector**
 - **PAD pointing vector**
 - **Geoid grid** (GLA ANC 13)
 - **Tide coefficients** (GLA ANC 15-17)
 - **DEM** (GLA ANC 13)
 - **Time**
 - **Waveform characteristics**

ELEVATION SUBSYSTEM

- **Level 1B and 2 Outputs**
 - **GLA06 Elevation File parameters**
 - **GLA12 Ice Sheet Products File parameters**
 - **GLA13 Sea Ice Products File parameters**
 - **GLA14 Land Products File parameters**
 - **GLA15 Ocean Products File parameters**
 - **GLA ANC06 QA parameters**

ELEVATION SUBSYSTEM

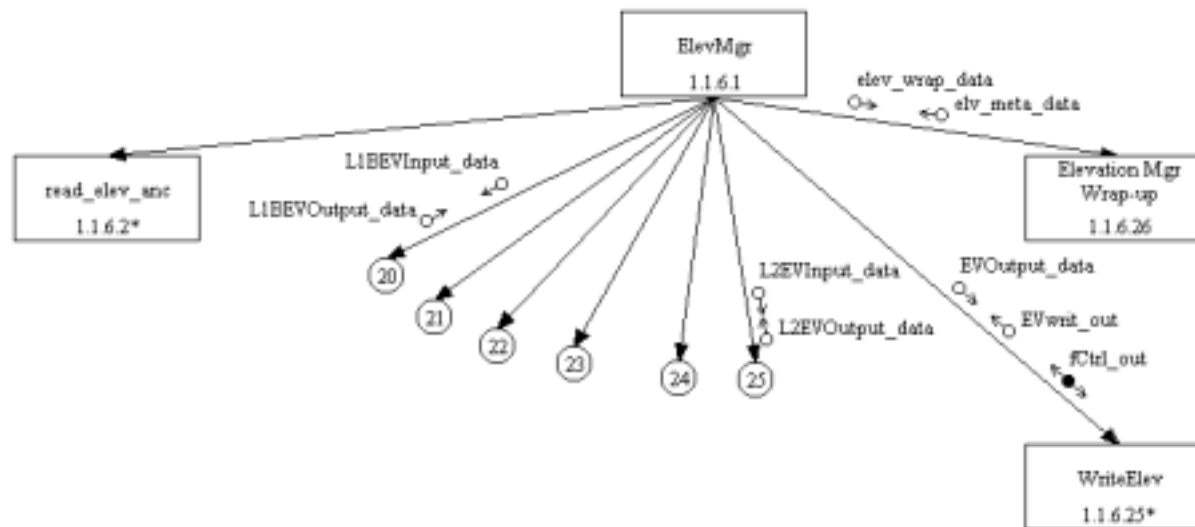
Levels 1B and 2



Level 1B and 2 Elevation DFD

ELEVATION SUBSYSTEM

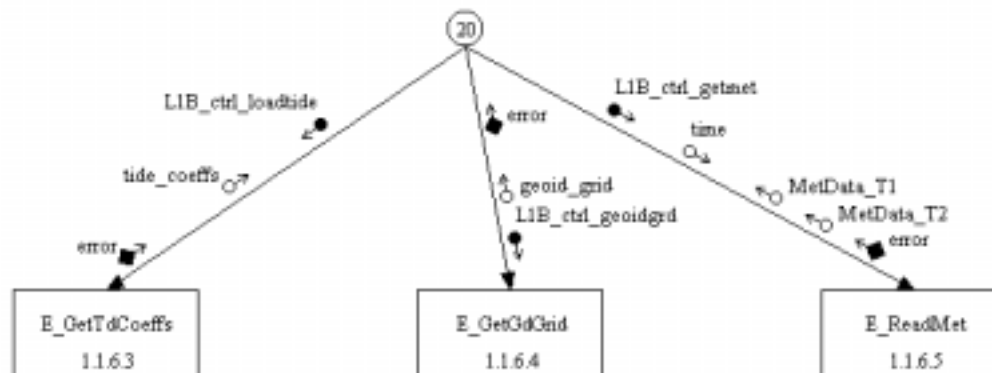
Levels 1B and 2



Elevation Processing Manager Structure Chart

ELEVATION SUBSYSTEM

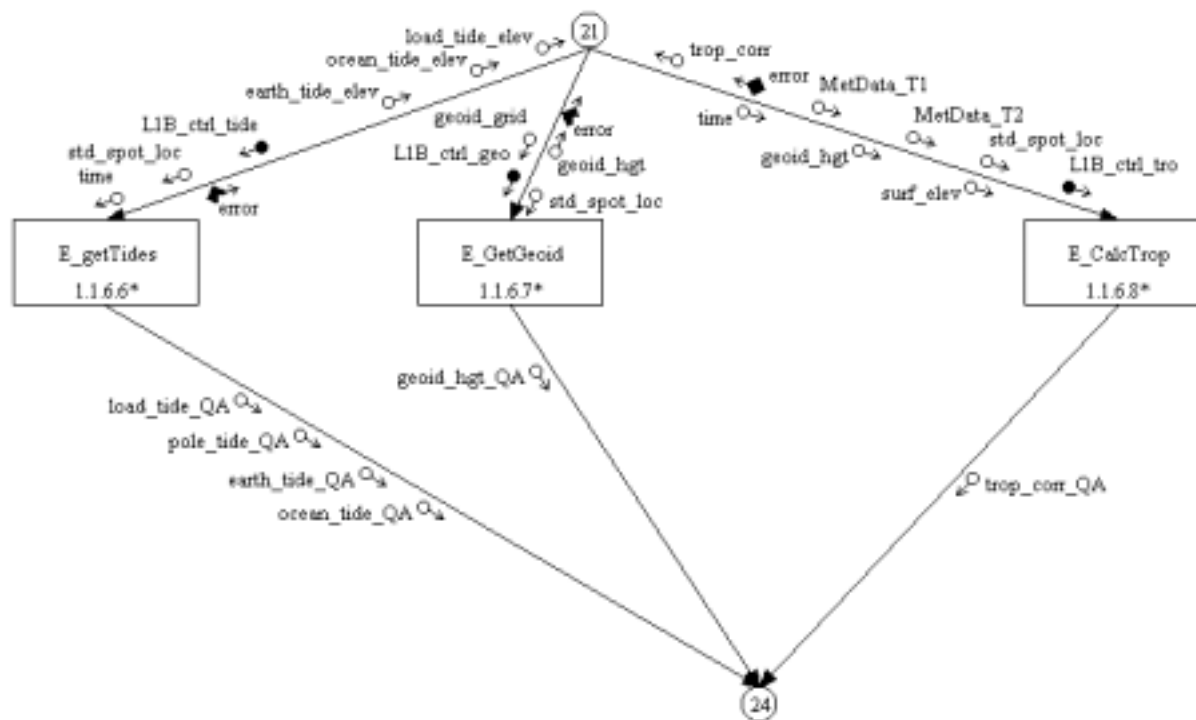
Levels 1B



Level 1 Elevations Structure Chart

ELEVATION SUBSYSTEM

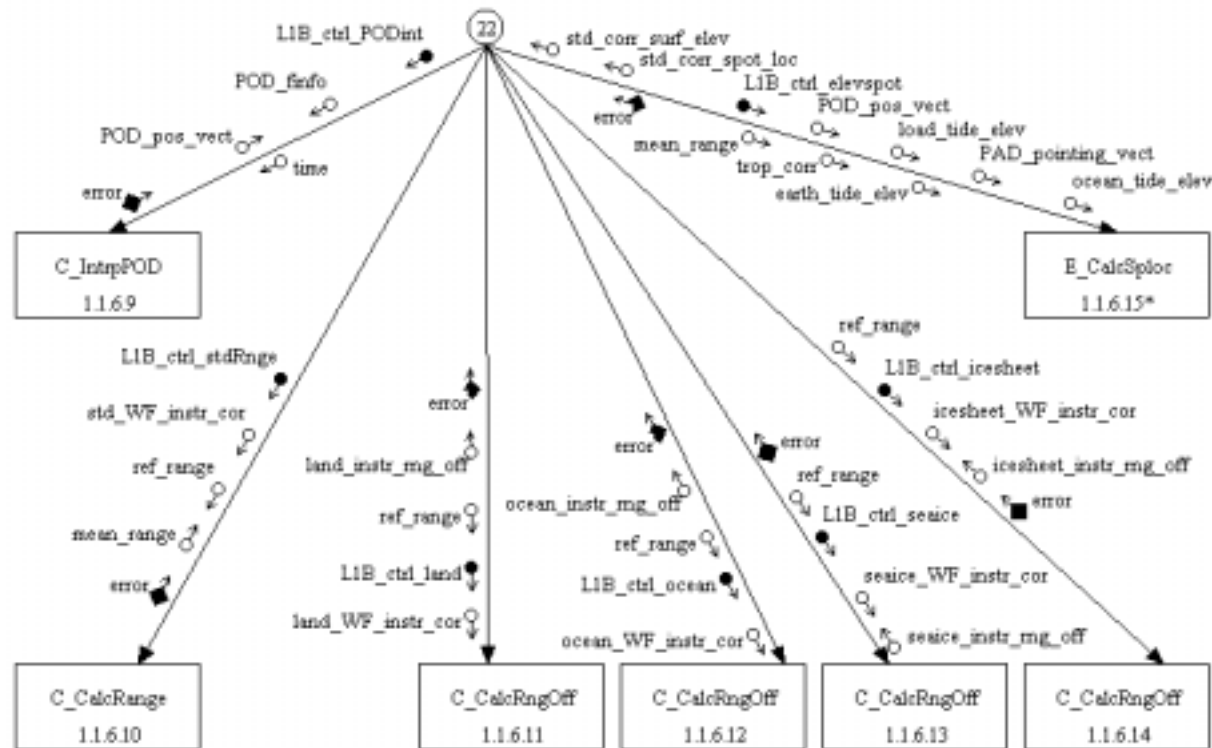
Levels 1B



Level 1 Elevations Structure Chart (continued)

ELEVATION SUBSYSTEM

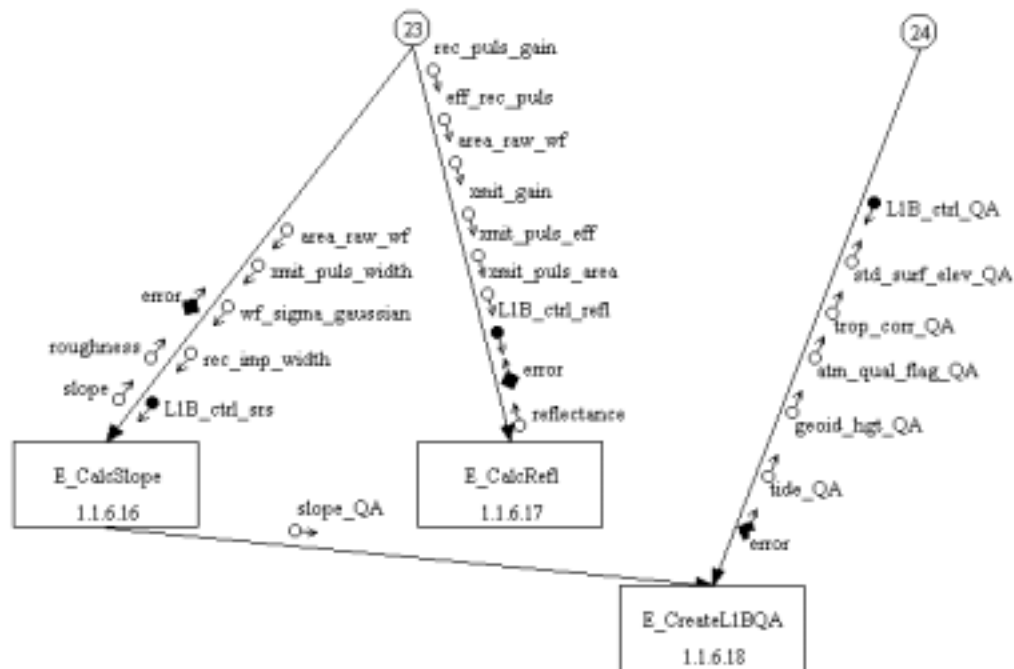
Levels 1B



Level 1 Elevations Structure Chart (continued)

ELEVATION SUBSYSTEM

Levels 1B



Level 1 Elevations Structure Chart (continued)

ELEVATION SUBSYSTEM

Levels 1B

Variables					State							
POD	Yes	No	No	No	No	No	No	No	No	No	No	No
PAD	No	Yes	No	No	No	No	No	No	No	No	No	No
Met Data	No	No	Yes	No	No	No	No	No	No	No	No	No
Std Instr Range	No	No	No	Yes	No	No	No	No	No	No	No	No
Land Instr Range	No	No	No	No	Yes	No	No	No	No	No	No	No
Ocean Instr Range	No	No	No	No	No	Yes	No	No	No	No	No	No
Sea Ice Instr Range	No	No	No	No	No	No	Yes	No	No	No	No	No
Ice Sheet Instr Range	No	No	No	No	No	No	No	Yes	No	No	No	No
Load Tide Model	No	No	No	No	No	No	No	No	Yes	No	No	No
Ocean Tide Model	No	No	No	No	No	No	No	No	No	Yes	No	No
Earth Tide Model	No	No	No	No	No	No	No	No	No	No	Yes	No
Geoid Model	No	No	No	No	No	No	No	No	No	No	No	Yes
Action												
Level 1B Elevation												
Load Tide Corr	No	No	No	No	No	No	No	No	Yes	No	No	No
Ocean Tide Corr	No	No	No	No	No	No	No	No	No	Yes	No	No
Earth Tide Corr	No	No	No	No	No	No	No	No	No	No	Yes	No
Geoid Hgt	No	No	No	No	No	No	No	No	No	No	No	Yes
Trop Corr	No	No	Yes	No	No	No	No	No	No	No	No	No
Std Instr Range	No	No	No	Yes	No	No	No	No	No	No	No	No
Land Instr Range	No	No	No	No	Yes	No	No	No	No	No	No	No
Ocean Instr Range	No	No	No	No	No	Yes	No	No	No	No	No	No
Sea Ice Range	No	No	No	No	No	No	Yes	No	No	No	No	No
Ice Sheet Range	No	No	No	No	No	No	No	Yes	No	No	No	No
Interp POD	Yes	No	No	No	No	No	No	No	No	No	No	No
Calc Std Elev & Spot	Yes	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	No
Calc Quality Flag	Yes?	Yes?	No	No	No	No	No	No	No	No	No	No
Calc Slope & Roughness	No	No	No	No	No	No	No	No	No	No	No	No
Calc Reflectance	No	No	No	No	No	No	No	No	No	No	No	No
Create L1B Quality Stats	No	No	No	No	No	No	No	No	No	No	No	No

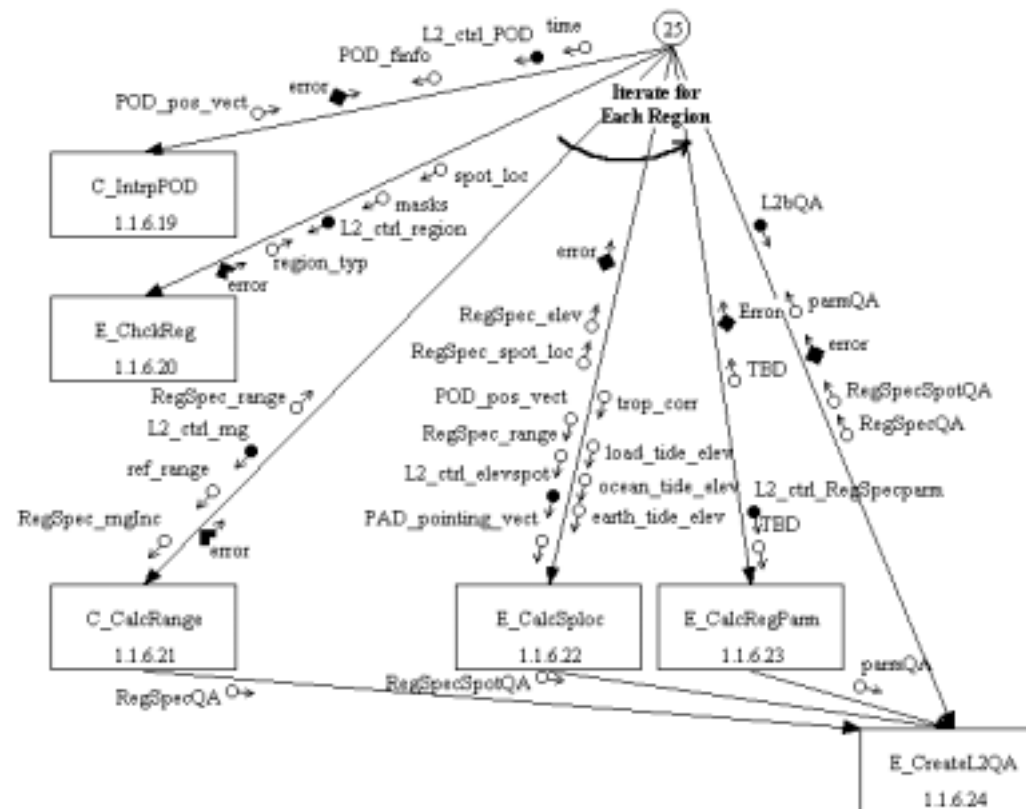
Reprocessing Scenario Stages For Level 1B Elevation

Level 1 Elevations State Diagram



ELEVATION SUBSYSTEM

Level 2



Level 2 Elevations Structure Chart

ELEVATION SUBSYSTEM

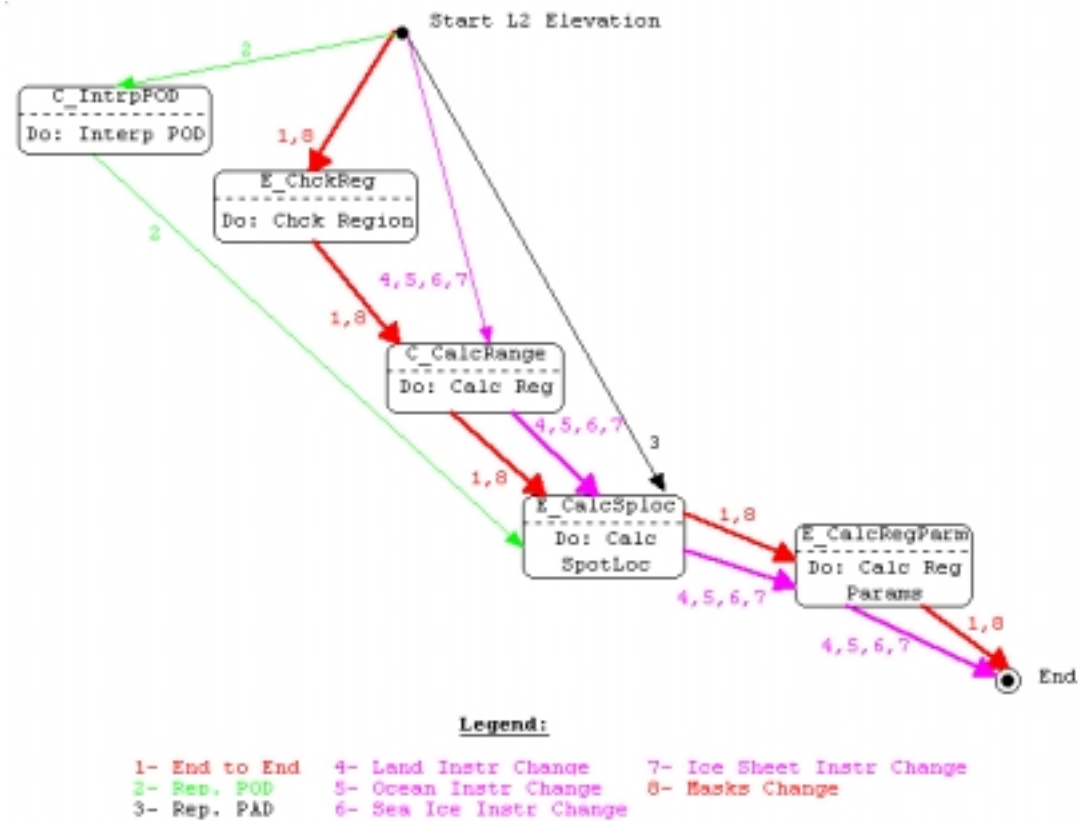
Level 2

Variables					State					
POD	Yes	No	No	No	No	No	No	No	No	No
PAD	No	Yes	No	No	No	No	No	No	No	No
Land Instr Range	No	No	Yes	No	No	No	No	No	No	No
Ocean Instr Range	No	No	No	Yes	No	No	No	No	No	No
Sea Ice Instr Range	No	No	No	No	Yes	No	No	No	No	No
Ice Sheet Instr Range	No	No	No	No	No	Yes	No	No	No	No
Land mask	No	No	No	No	No	No	Yes	No	No	No
Ocean mask	No	No	No	No	No	No	No	Yes	No	No
Sea Ice mask	No	No	No	No	No	No	No	No	Yes	No
Ice Sheet Mask	No	No	No	No	No	No	No	No	No	Yes
Action										
Level 2 Elevation										
Interp POD	Yes	No	No	No	No	No	No	No	No	No
Check region	No	No	No	No	No	No	Yes	Yes	Yes	Yes
Calc Region Sp Range	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Calc SpotLoc	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Reprocessing Scenario Stages For Level 2 Elevation

ELEVATION SUBSYSTEM

Level 2



Level 2 Elevations State Diagram

ELEVATION SUBSYSTEM

- **Errors**

- | | |
|----------------------------------|------------------|
| – File I/O errors | Action: Critical |
| – No POD file for time of data | Action: Critical |
| – Incorrect value read from file | Action: Warning |
| – Exceed Maximum iterations | Action: Warning |
| – Off-nadir pointing > spec. | Action: Warning |
| – Height > max ht in Met File | Action: Warning |
| – Height < min ht in Met File | Action: Warning |
| – Arithmetic Errors | Action: Warning |

ELEVATION SUBSYSTEM

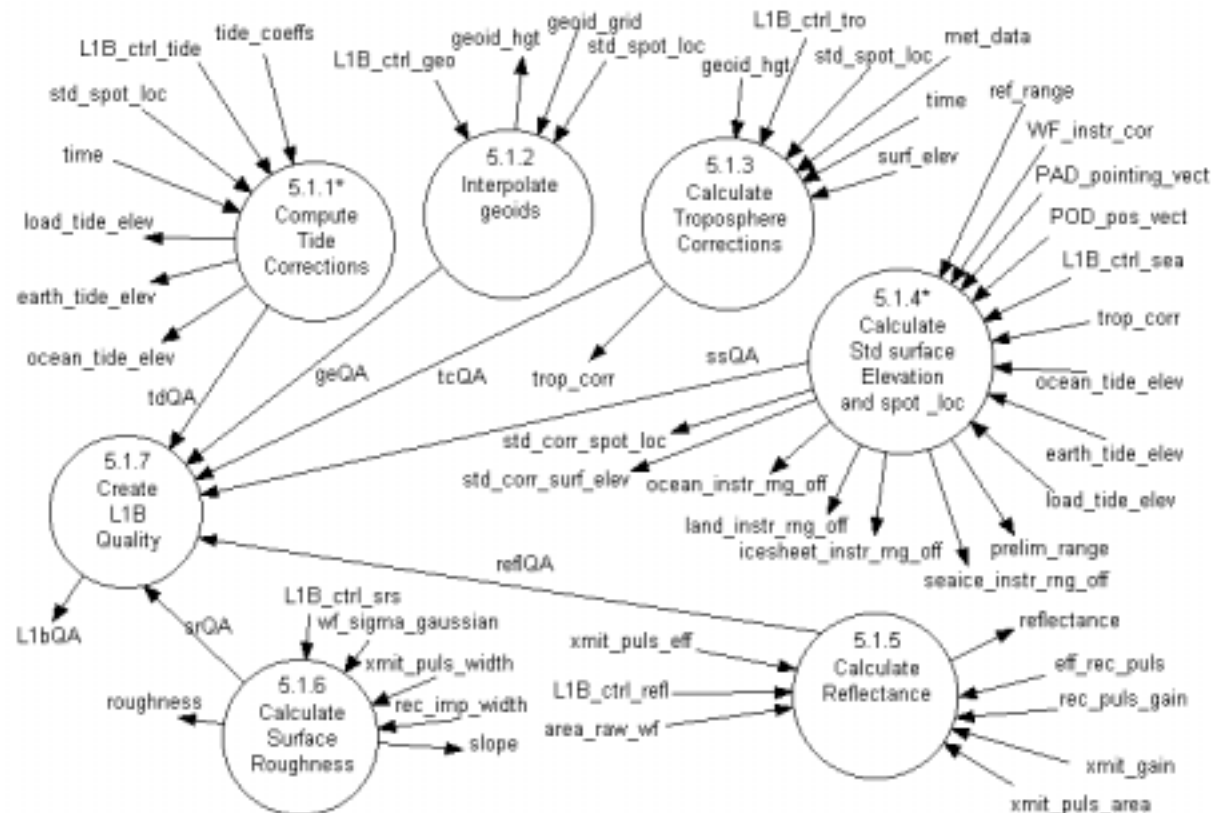
- **Status**
 - **Coded Met Delay Corrections module, and tested using code supplied by Science Team**
 - **Coded Geolocation module, currently testing using data provided by Science Team**
 - **Coded Interp POD module, currently testing using data provided by Science Team**
 - **Developing Tidal Corrections modules, which will be tested using data provided by Science Team**

ELEVATION SUBSYSTEM

Supplemental Material

ELEVATION SUBSYSTEM

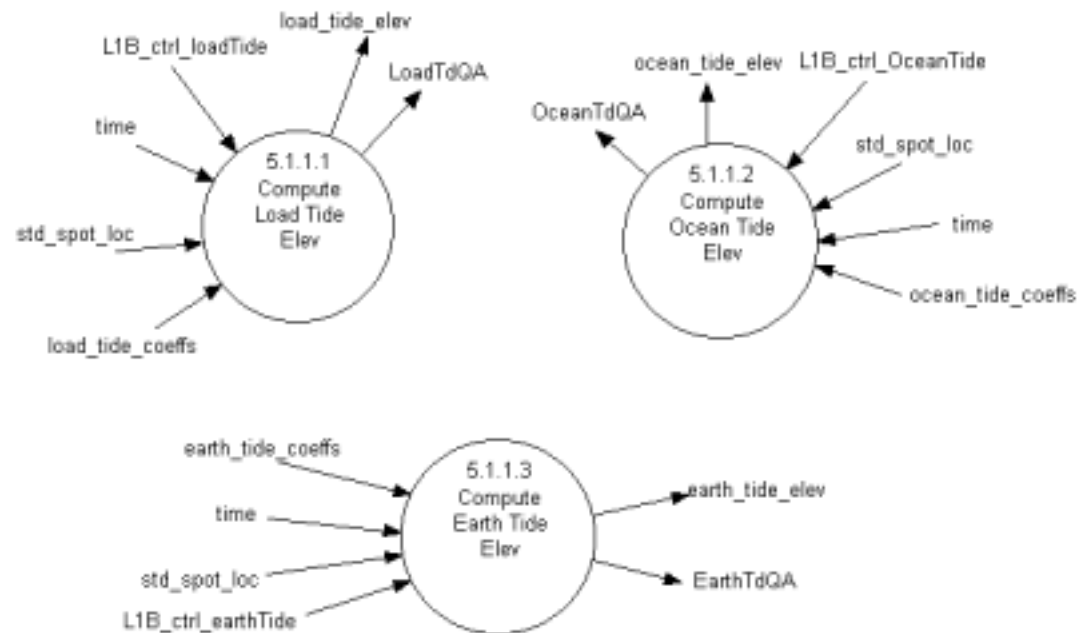
Level 1B



Level 1B Elevation Computation DFD

ELEVATION SUBSYSTEM

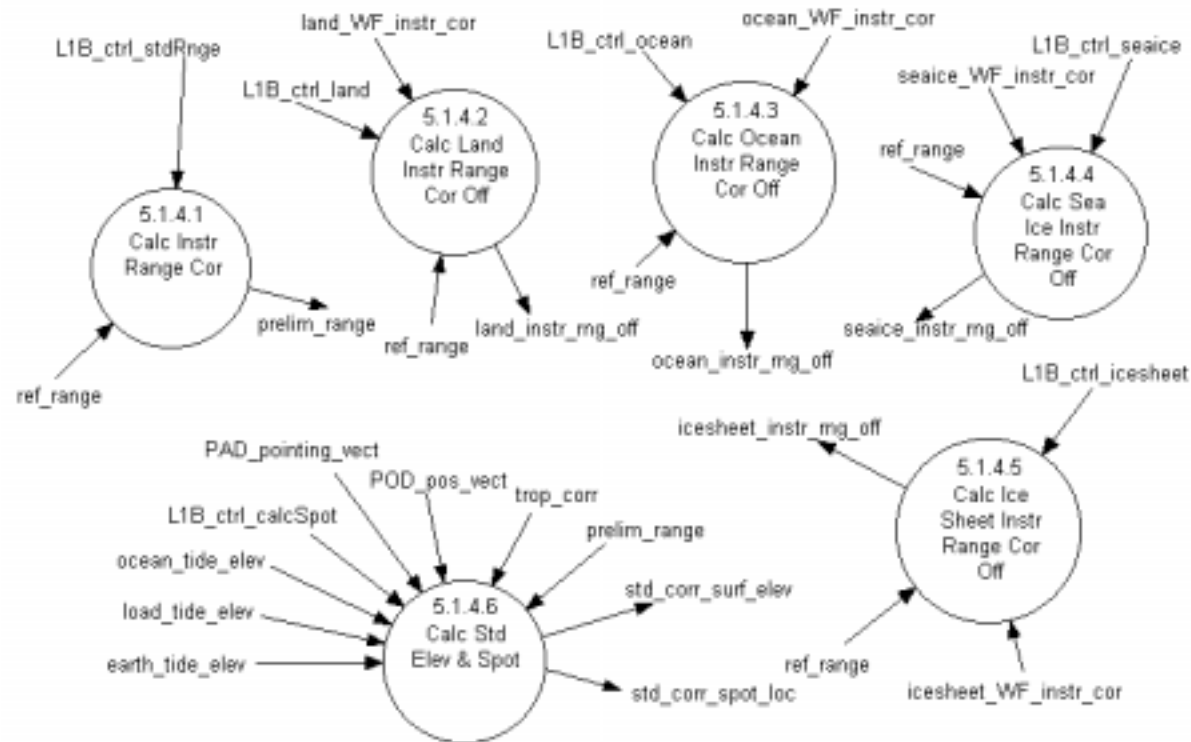
Level 1B



Compute Tide Corrections DFD

ELEVATION SUBSYSTEM

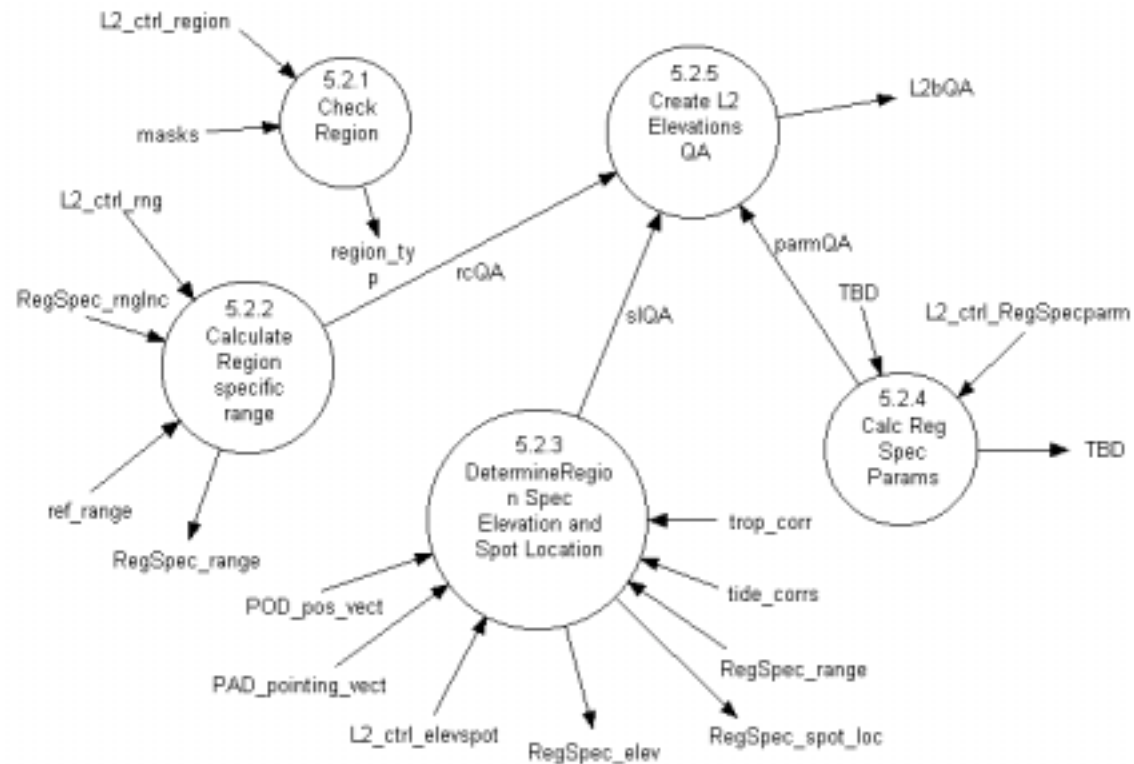
Level 1B



Calculate Std Surface Elevation and Spot Loc DFD

ELEVATION SUBSYSTEM

Level 2



Level 2 Elevations DFD

ATMOSPHERE ATBD SUMMARY/PRODUCTS

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ATMOSPHERIC MEASUREMENTS

- **532 Channel:** Molecular, aerosol and cloud backscatter during both day and night using 8 photon counting detectors and actively-tuned, narrow-band etalon filter (25 pm)
- **1064 Channel:** Cloud backscatter during day and night using SI APD detector and 8 bit A/D
 - $S(z)$ - received signal
- **C** - system calibration constant
- **E** - Laser Energy
- $\beta(z)$ - atmospheric backscatter cross section
- $T^2(z)$ - two-way path atmospheric transmission
- **R** - Range from satellite to z
- P_b and P_d - Solar background and detector dark current
- **Horizontal Resolution:**
 - 1 to 10 km - Full resolution (40 Hz) or 175 meters
 - 10 to 20 km - Sum of 8 shots (5 Hz) or 1.4 km
 - 20 to 40 km - Sum of 40 shots (1 Hz) or 7.5 km (532 only)
- **Vertical Resolution:**
 - 76.8 meters (1.953 MHz)

$$S(z) = \frac{CE\beta(z)T^2(z)}{R^2} + P_b + P_d$$

ATMOSPHERE SUBSYSTEM

- **Level 1B**

- GLA07 - Calibrated Backscatter**

- **Level 2**

- GLA08 - PBL and Aerosol Layer Heights**

- GLA09 - Cloud Layer Heights**

- GLA10 - Attenuation Corrected Backscatter and
Extinction Profiles**

- GLA11 - Thin Cloud and Aerosol Layer Optical Depth**

ATMOSPHERE SUBSYSTEM

GLA07 - Calibrated Backscatter Profiles

Inputs

- **Normalized Lidar Signals (GLA02)**
- **MET Data (GLA ANC 01)**
- **Standard Atmosphere P,T,RH (GLA ANC 18)**
- **POD Position Vector**
- **Range from satellite to start of data**
- **Time**

Outputs

- **5 Hz calibrated backscatter profiles from 40 to -1 km (532) and 20 -1 km (1064)**
- **40 Hz calibrated backscatter profiles from 10 to -1 km (532 and 1064)**
- **532 and 1064 calibration constants**
- **1 Hz molecular backscatter profiles (532 and 1064)**
- **Laser energy quality flag**
- **Boresite quality flag**
- **Calibration constant quality flags**

ATMOSPHERE SUBSYSTEM

GLA08 - PBL and Aerosol Layer Heights

Inputs

- **5 Hz calibrated backscatter profiles (GLA07)**
- **Molecular backscatter profiles (GLA07)**
- **Cloud layer locations (GLA09)**
- **Location of ground return (GLA09)**
- **MET data**

Outputs

- **Planetary Boundary Layer (PBL) height at 5 Hz and 4 seconds**
- **Aerosol layer top and bottom above 20 km at 20 seconds (max 3 layers)**
- **Aerosol layer top and bottom, below 20 km at 4 seconds (max 5 layers)**
- **Polar Stratospheric Cloud (PSC) flag**
- **PBL and aerosol layer height quality flags**
- **PBL clear/cloudy flag**

ATMOSPHERE SUBSYSTEM

GLA09 - Cloud Layer Heights

Inputs

- **5 and 40 Hz calibrated (532) backscatter profiles (GLA07)**
- **Molecular backscatter profiles**
- **POD data**

Outputs

- **Cloud layer top and bottom height for maximum of 10 layers at .25 Hz, 1 Hz, and 5 Hz**
- **Cloud boundary at 40 Hz for one layer below 4 km**
- **Ground height**
- **Quality flags for cloud layers**

ATMOSPHERE SUBSYSTEM

GLA10 - Attenuation corrected Backscatter and Extinction Profiles

Inputs

- **5 Hz calibrated (532) backscatter profiles (GLA07)**
- **Aerosol layer product (GLA08)**
- **Cloud layer product (GLA09)**
- **MET data and POD location**
- **Molecular backscatter profiles**

Outputs

- **532 cloud attenuation corrected backscatter and extinction profiles at 1 Hz**
- **532 aerosol attenuation corrected backscatter and extinction profiles at 0.25 Hz**
- **Backscatter to extinction ratios for cloud and aerosol layers**
- **Quality flags**

ATMOSPHERE SUBSYSTEM

GLA11 - Cloud and Aerosol Layer Optical Depths

Inputs

- **5 Hz calibrated (532) backscatter profiles (GLA07)**
- **Aerosol layer product (GLA08)**
- **Cloud layer product (GLA09)**
- **Molecular backscatter profiles**

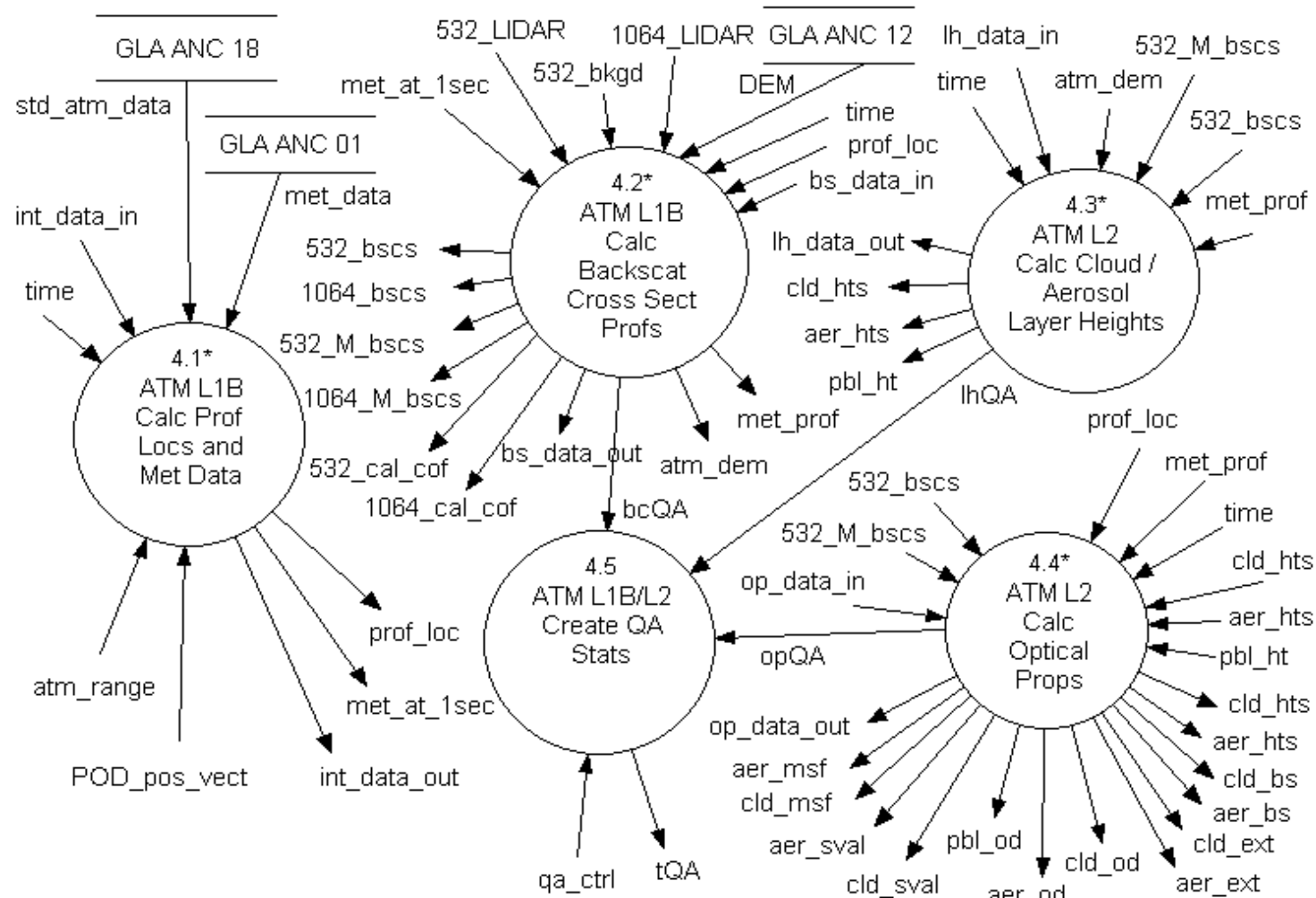
Outputs

- **532 cloud optical depth at 1 Hz for up to 10 layers**
- **532 aerosol optical depth at 0.25 Hz for up to 8 layers and the boundary layer**
- **Multiple scattering warning flag**
- **Quality flags**

ATMOSPHERE SUBSYSTEM

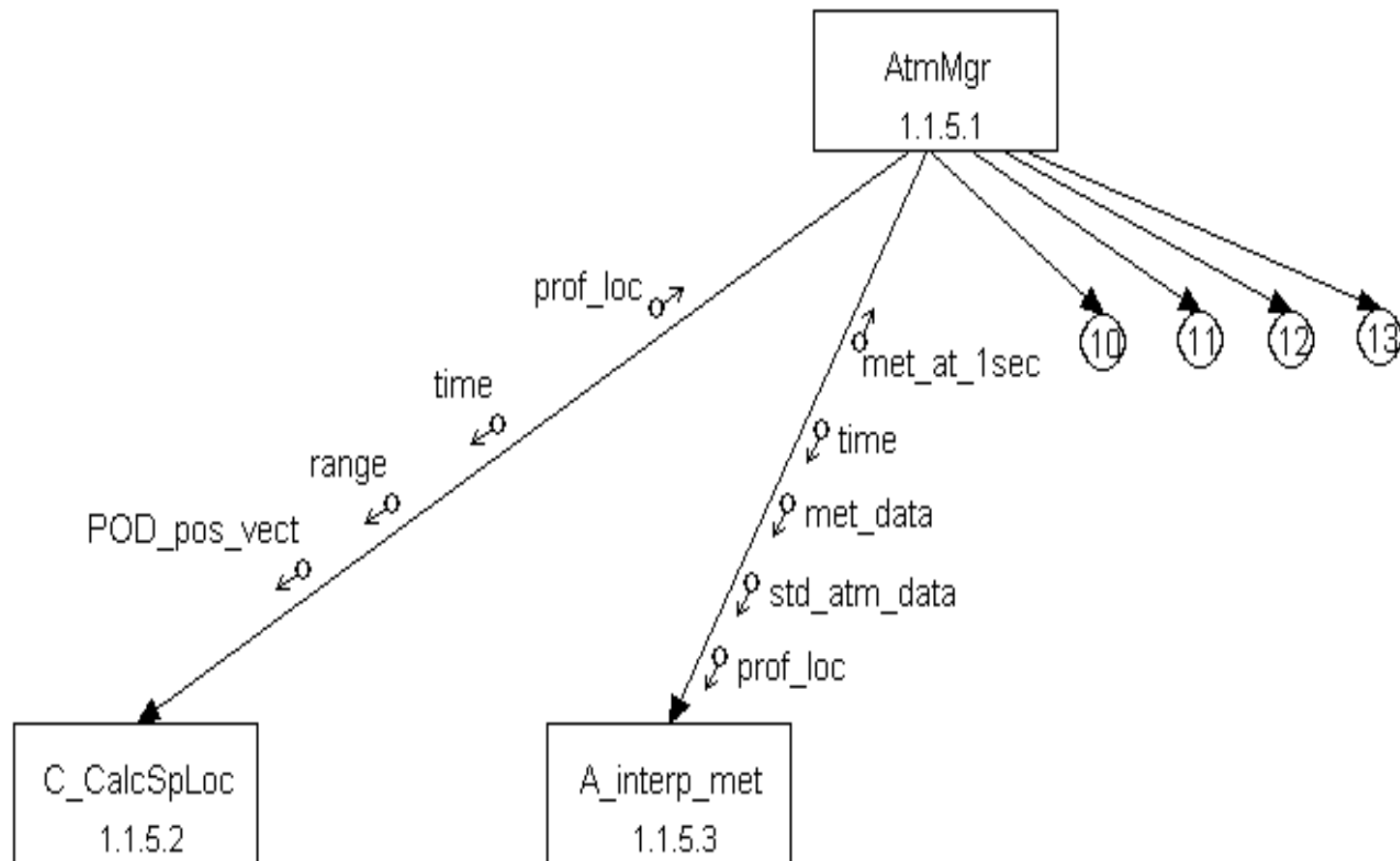
- **Requirements**
 - **Implement GLAS Atmospheric Data Products ATBD version 3.0**
 - **Create level 1B attenuated backscatter cross section profiles**
 - **Create level 2 cloud, aerosol, and PBL layer heights**
 - **Create level 2 cloud, aerosol, and PBL backscatter and extinction cross section profiles**
 - **Create level 2 cloud, aerosol, and PBL optical depths**
 - **Create level 1B and 2 QA statistics**
 - **Create level 1B and 2 browse products**

ATMOSPHERE SUBSYSTEM



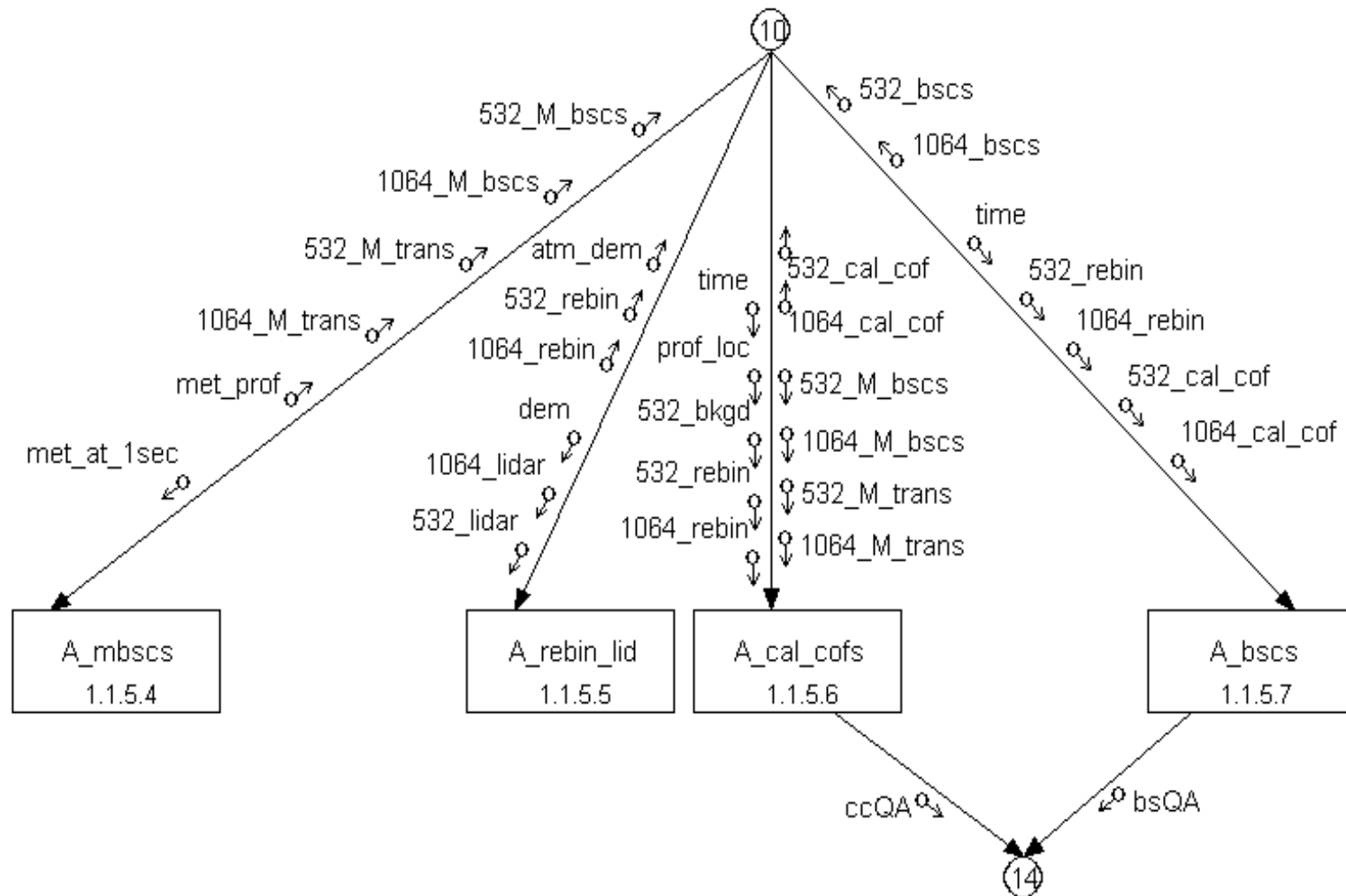
Level 1B and 2 Atmosphere Computations DFD

ATMOSPHERE SUBSYSTEM



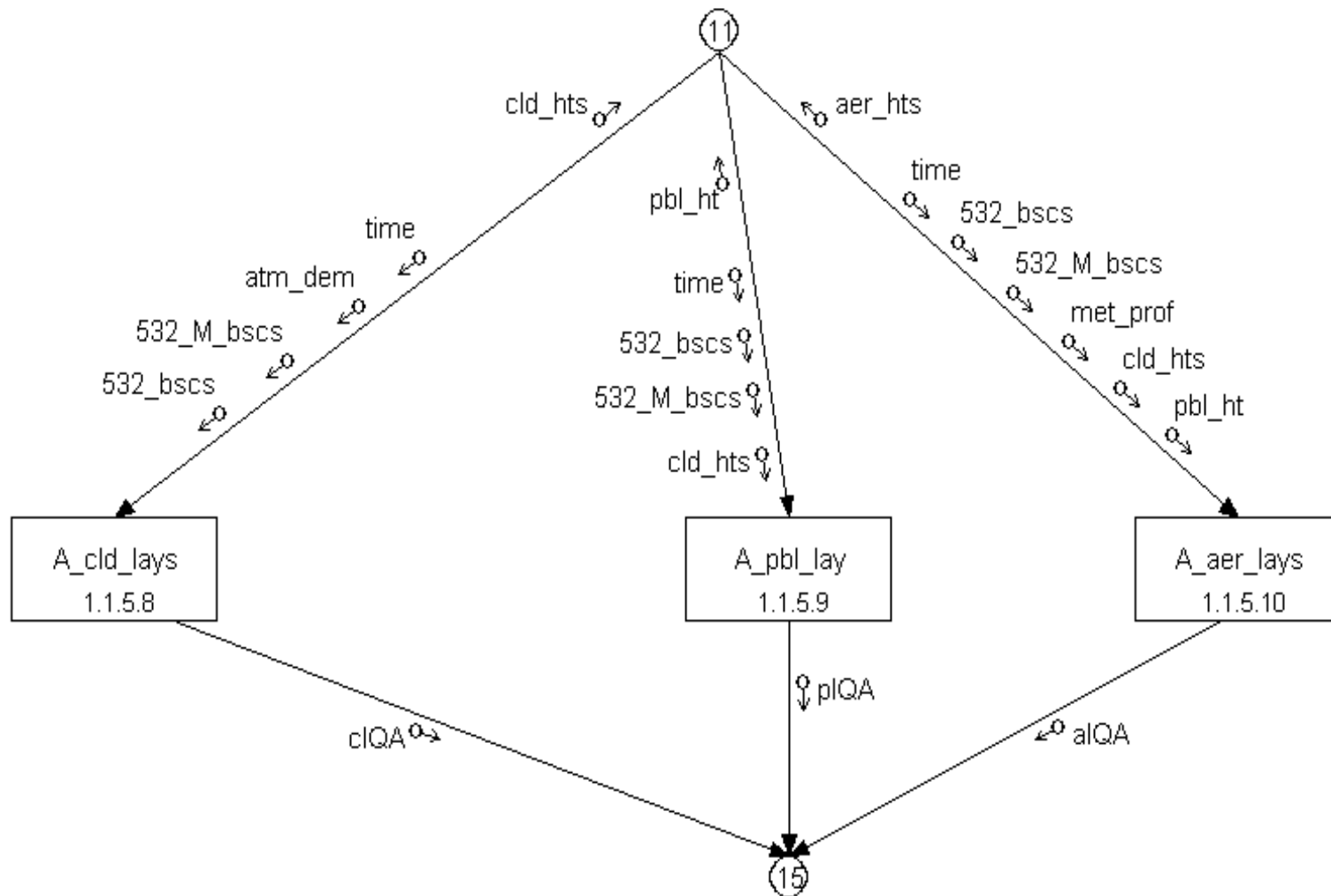
Profile Location / Met Section Structure Chart

ATMOSPHERE SUBSYSTEM



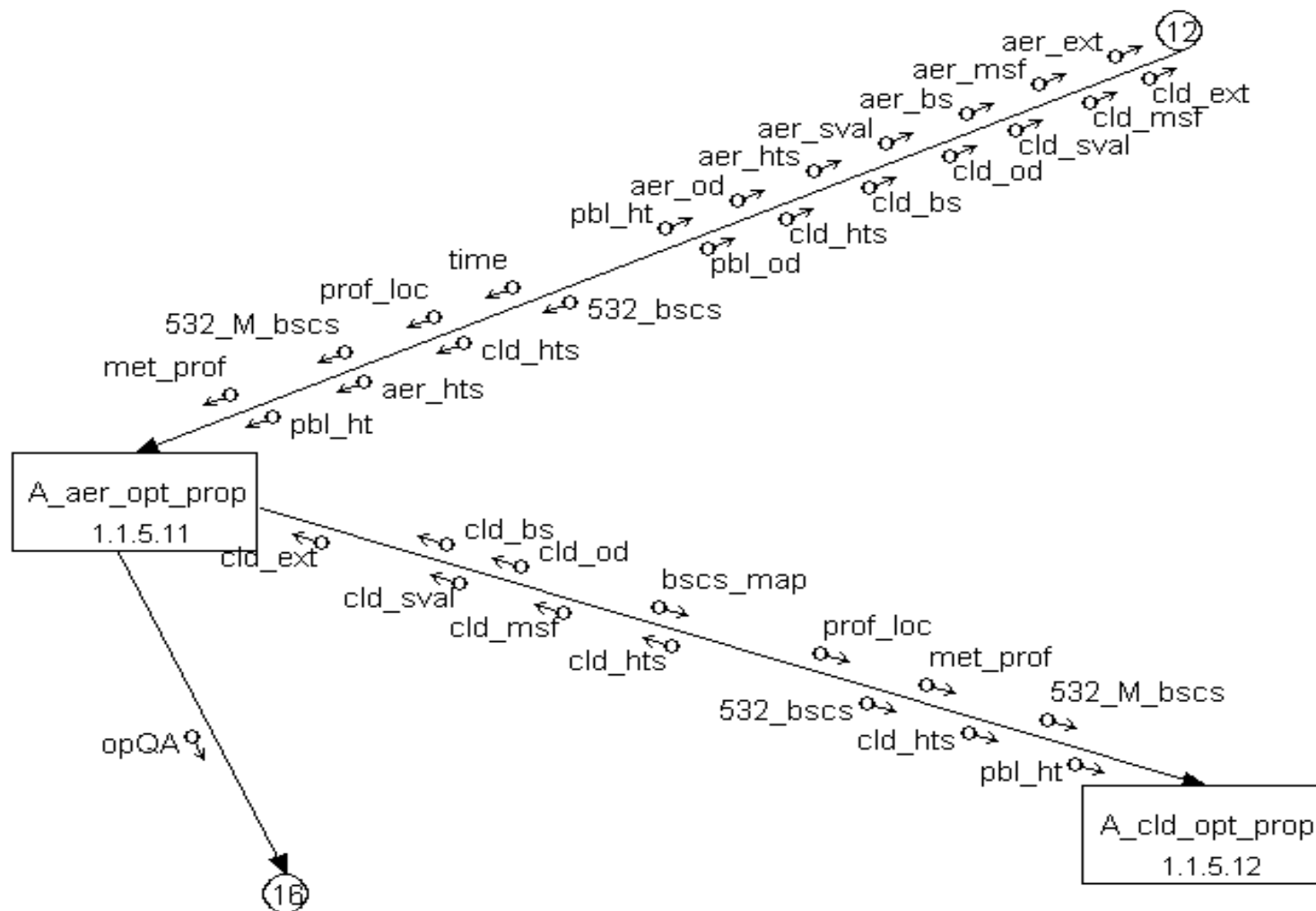
Backscatter Section Structure Chart

ATMOSPHERE SUBSYSTEM



Cloud/Aerosol Layers Section Structure Chart

ATMOSPHERE SUBSYSTEM



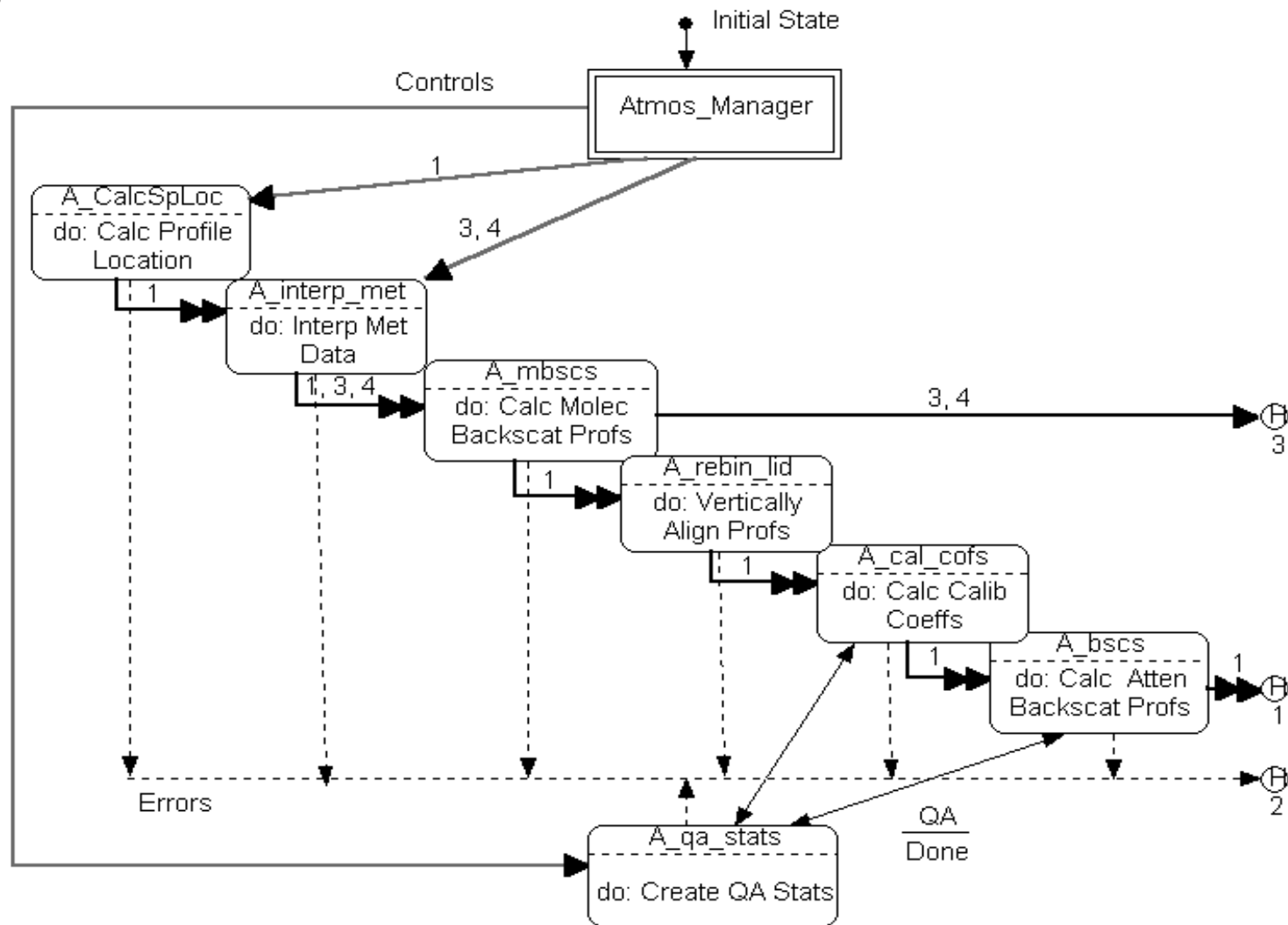
Optical Properties Section Structure Chart

ATMOSPHERE SUBSYSTEM

Variables										
POD_pos_vect	Yes	No	No	No	No	No	No	No	No	
Met Data	No	Yes	No	No	No	No	No	No	No	
GLA02	No	No	Yes	No	No	No	No	No	No	
GLA07	No	No	No	Yes	No	No	No	No	No	
GLA08	No	No	No	No	Yes	No	No	No	No	
GLA09	No	No	No	No	No	Yes	No	No	No	
GLA10	No	No	No	No	No	No	Yes	No	No	
GLA11	No	No	No	No	No	No	No	No	Yes	
Action										Product
C_CalcSpLoc	Yes	Yes	Yes	Yes	No	No	No	No	No	
A_interp_met	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
A_mbscs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
A_rebin_lid	Yes	Yes	Yes	Yes	No	No	No	No	No	
A_cal_cofs	Yes	Yes	Yes	Yes	No	No	No	No	No	
A_bscs	Yes	Yes	Yes	Yes	No	No	No	No	No	GLA07
A_cld_lays	Yes	Yes	Yes	Yes	No	Yes	No	No	No	GLA09
A_pbl_lay	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	
A_aer_lays	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	GLA08
A_aer_opt_prop	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	GLA10-11

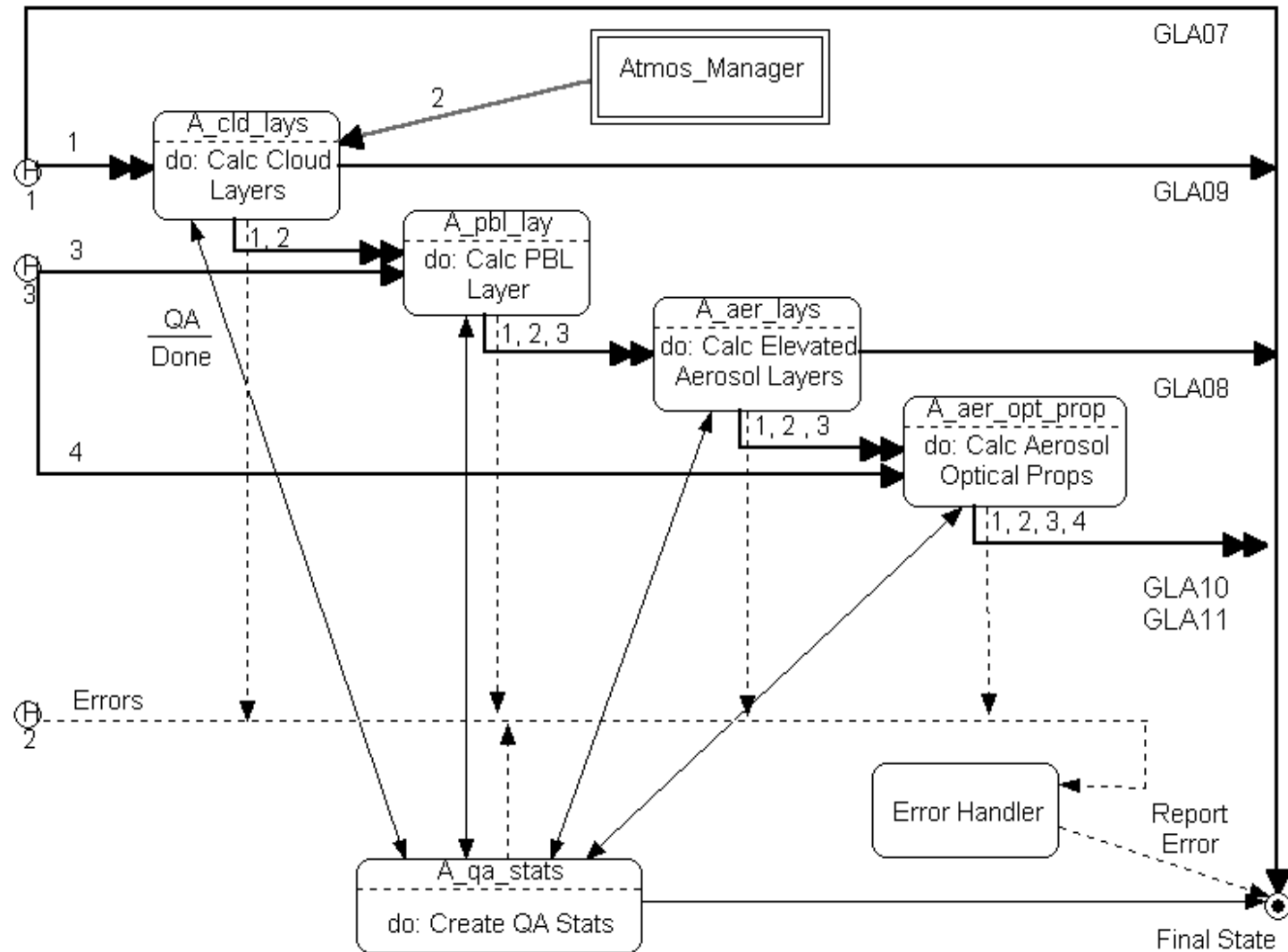
Reprocessing Decision Table

ATMOSPHERE SUBSYSTEM



State Transition Diagram

ATMOSPHERE SUBSYSTEM



State Transition Diagram

ATMOSPHERE SUBSYSTEM

- **Errors (partial list)**
 - **532 integrated return flag poor or bad** **Warning**
 - **Ratio of integrated returns out-of-bounds** **Warning**
 - **Deficient 532/1064 laser energy flags** **Warning**
 - **Large number bad recs not incl in data** **Warning**
 - **Time between recs greater than threshold** **Warning**
 - **Divide by zero** **Warning**
 - **Exponent too large** **Warning**

Note: There are no critical errors for this subsystem

ATMOSPHERE SUBSYSTEM

- **QA Statistics per Granule (partial list)**
 - **Avg number of cloud layers detected**
 - **Pct of time one or more cloud layers were detected**
 - **Avg and standard deviation of PBL height**
 - **Avg number of elevated aerosol layers detected**
 - **Avg cloud, PBL, aerosol optical depth values**
 - **Pct of cloud/aerosol layers not optically processed because transmission calculation out of bounds**

ATMOSPHERE SUBSYSTEM

- **Browse Products**
 - **532/1064 calibration coefficients vs. time**
 - **532 integrated return from 41 to 20 km vs. time**
 - **Cloud/aerosol optical depths vs. time**
 - **Images of 532 backscatter profiles with cloud, PBL, and aerosol layers overlaid**

ATMOSPHERE SUBSYSTEM

- **Subsystem Unit Testing**
 - **Backscatter: Tested using simulated data furnished by lidar science team - Passed**
 - **Optical Properties: Currently being tested using simulated data furnished by lidar science team.**
 - **Cloud/Aerosol Layers: Will be tested using simulated data furnished by lidar science team.**

ATMOSPHERE SUBSYSTEM

- **Schedule/Status (man days remaining)**

ATM Manager	33	PDL/preliminary coding
Prof Loc/Met	54	PDL/preliminary coding
Backscatter Profiles	12	Integration
Cloud/Aerosol Layers	121	PDL/preliminary coding
Optical Properties	23	Unit Testing
Quality Statistics	54	Not started yet

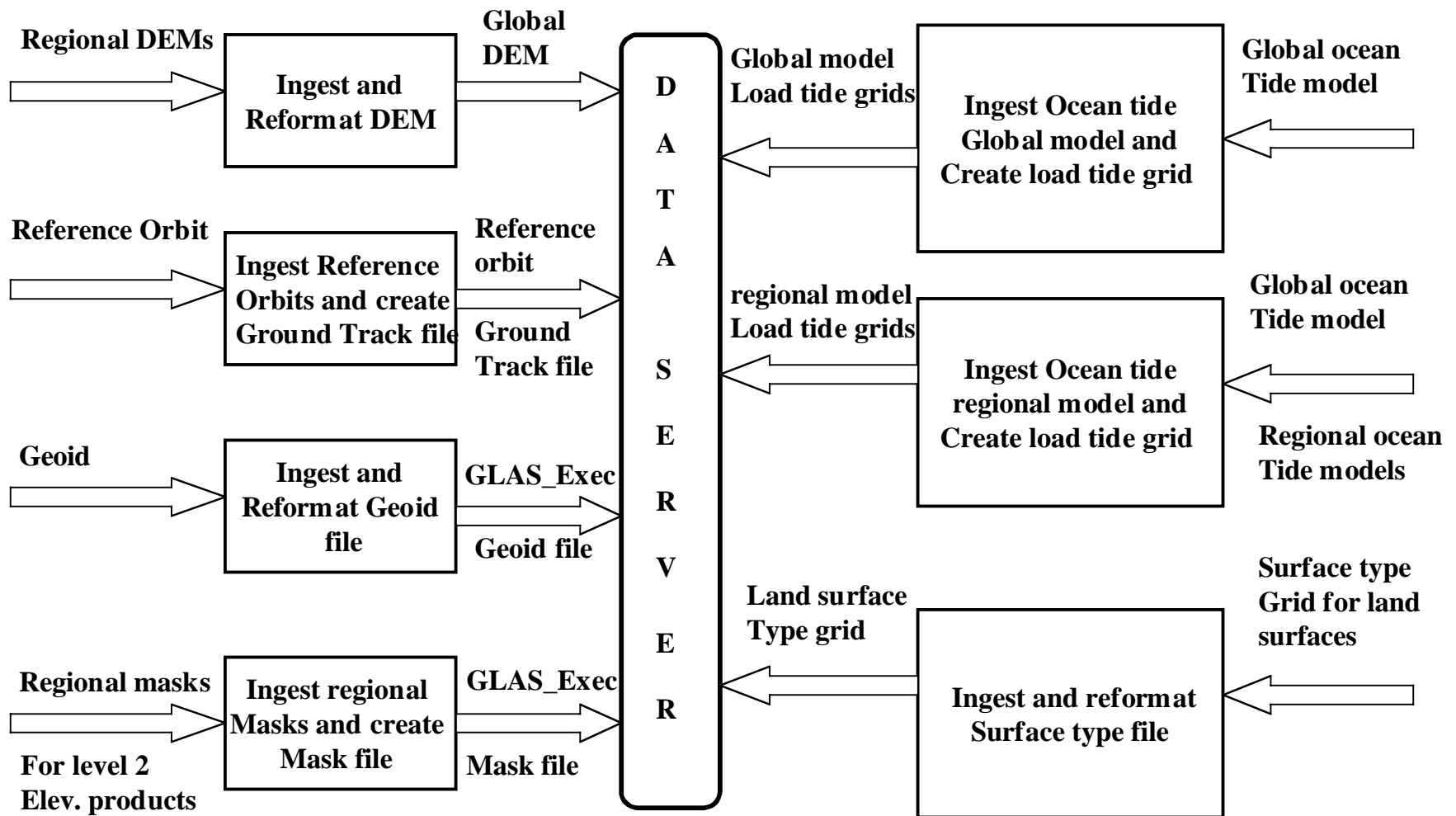
STAND-ALONE UTILITIES FOR I-SIPS SCIENCE SOFTWARE PROCESSING

**Anita Brenner
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Greenbelt, MD 20771
email: anita@icesat2.gsfc.nasa.gov
phone: (301) 614-5914**

STAND-ALONE UTILITIES

- **Divided into two groups**
 - **Utilities executed infrequently – based on static or near-static input**
 - **Utilities executed routinely as part of daily production processing**

UTILITIES CREATED FROM STATIC FILES REQUIRED FOR GLAS STANDARD PRODUCTS



REFERENCE ORBIT GROUND TRACK FILE CREATION

- **Input**
 - Ephemeris of reference orbit in same format as Precision Orbit Files
 - Orbit interpolator software (exists, may need modification to accept format)
- **Utility - functionality**
 - Find time and longitude of all equator crossings in the predicted file – this can be done iteratively
 - Using a specific delta t – start with that of the ephemeris – find the records before and after the ascending node and write to a file
 - Repeat above process, each time using a smaller time increment until getting the equator crossing time at the desired accuracy
 - Use the orbit interpolator to interpolate for the latitude and longitude every 1 sec (or different interval if more appropriate, `deltat_reforb`) from the time of the ascending node until the end of the rev
- **Triggers – frequency 2- 6 times per mission**
 - New reference orbit

REFERENCE ORBIT GROUND TRACK FILE CREATION

(continued)

- **Output – one direct access file with one record/track**
 - Period of the track in milliseconds
 - longitude of the ascending node
 - two arrays – one of latitude and one of longitude for every `deltat_reforb` from the ascending node
- **Information to keep track of**
 - Reference orbit id
 - Reference orbit ground track file name
 - Time of beginning of the reference orbit
 - Instance of this reference orbit
 - Track and index of beginning of this instance
- **Used by**
 - SCF visualization software
 - SCF data selection software
 - GLAS_EXEC

CREATE DEM FILE FOR GLAS_EXEC

- **Input**
 - Regional DEMs – from multiple sources
- **Utility Functionality**
 - Merge DEMs into one DEM file where every record corresponds to a latitude and contains an array of DEM values all longitudes
- **Triggers – 2 to 6 times per mission**
 - New DEM
- **Output**
 - GLAS_EXEC DEM file
- **Information to keep track of**
 - DEM IDs
 - Location and dsn of merged DEM file
 - Resolution of DEM file
- **Used by**
 - GLAS_EXEC

INGEST AND REFORMAT GEOID FILE

- **Inputs**
 - Global geoid grid
- **Utility functionality**
 - Ingest geoid into data management
 - Reformat into a 2-D array in lat/lon in format expected by GLAS_EXEC
- **Triggers – 2 –6 times per mission**
 - New geoid file
- **Output –**
 - Geoid file used by GLAS_EXEC, on record per latitude with all longitude values
- **Information to keep track of**
 - Geoid id
 - Geoid latitude and longitude resolution
 - Name of geoid file to be used by GLAS_EXEC
- **Used by**
 - GLAS_EXEC

CREATE REGIONAL MASK DATA SET

- **Inputs**
 - Ocean mask
 - Land mask
 - Sea ice mask
 - Ice sheet mask
- **Utility functionality**
 - Create a lat/long grid that has a bit set for each of the above input masks so we can tell what region(s) satellite is over
- **Triggers – 2- 6 times per mission**
 - Any of the regional masks change
- **Output**
 - Direct access file one record per latitude value-each record holds all longitudes
 - Set of 4 bits telling whether we are over a specific region or not, multiple bits can be set
- **Information to keep track of**
 - Regional mask data set name
 - Individual region mask ids
- **Used by**
 - GLAS_EXEC

CREATE SURFACE TYPE FILE

- **Input**
 - **Surface type grid(s)**
- **Utility Functionality**
 - **merge into global surface type file**
- **Triggers – 2 to 6 times per mission**
 - **New surface type grid**
- **Output**
 - **Merged global surface type file, one record per latitude value for all longitudes**
- **Information to keep track of**
 - **Surface type grid IDs**
 - **Location and dsn of global surface type file**
 - **Resolution of file**
- **Used by**
 - **GLAS_EXEC**

CREATE GLOBAL LOAD TIDE GRID FOR DEFAULT GLOBAL OCEAN TIDE MODEL

- **Input**
 - Ocean tide model
- **Utility functionality**
 - Create a global 1 deg grid of the harmonics of each constituent defining the load tide
- **Triggers**
 - Receipt of new global ocean tide model
 - 1 or 2 per mission
- **Output**
 - Global 1 deg grid of load tide harmonics, one grid for each of 7 constituents
- **Used by**
 - GLAS_EXEC

CREATE LOAD TIDE GRID FOR REGIONAL OCEAN TIDE MODELS

- **Input**
 - Global Ocean tide model
 - Regional ocean tide model(s)
- **Utility functionality**
 - Create a 1 deg grid of the harmonics of each constituent defining the load tide for the region being defined
- **Triggers**
 - Receipt of new global or regional ocean tide model
 - 1 to 5 times per mission
- **Output**
 - Regional 1 deg grid of load tide harmonics, one grid for each of 7 constituents
- **Used by**
 - GLAS_EXEC

UTILITIES RUN DURING DAILY PRODUCTION

- **Utilities run before product creation**
 - Calculate granule start times and ascending node times
 - Create level 0 index files
 - Subset Met data files
 - Planning jobs that create control files
- **Utilities run after product creation**
 - Create trend data
 - Create Browse products
 - Perform automatic Quality Assurance
 - Verify products
 - Reformat products to HDF-EOS
 - Stage GLA04 to UTCSR
 - Stage products to ISF
 - Stage products to SCF
 - Stage products to NSIDC

CREATE REV ASCENDING NODE TABLE AND START TIMES FOR GRANULES

- **Input**
 - Predicted orbit
- **Utility functionality**
 - Create table of times and longitudes of each ascending node and each + or – 50 deg latitude crossing
- **Triggers – once per day**
 - Receipt of predicted orbit from UTCSR
- **Output**
 - table of times and longitudes of each ascending node and each + or – 50 deg latitude crossing
- **Information to keep track of**
 - Predicted orbit input file id
 - Times covered by the predicted orbit file
 - Location of output table
- **Used by**
 - Planner that creates cntl file input to GLAS_EXEC
 - GLAS_EXEC

CREATION OF LEVEL 0 DATA USE INDEX FILE

- **Input**
 - Level 0 file from EDOS
- **Utility functionality**
 - Create an index file that tells what records and what order to read them in from the level 0 file, in order to process only good data in time-order
- **Triggers – 4 times per day**
 - Receipt of level 0 file
- **Output**
 - Index file – one for each level 0 file received
- **Information to keep track up**
 - Index file id (dsn, version whatever uniquely defines it)
 - Level 0 file id (dsn, version, etc.) that corresponds to the index file
 - Time span of data in level 0 file
- **Used by**
 - GLAS_EXEC – level 1a processing

CREATE MET DATA FILES FOR PROCESSING

- **Input**
 - Met data from NSIDC DAAC
- **Utility functionality**
 - Create a file that is a subset of the DAAC met file containing only parameters we require for processing
- **Triggers - automatically 6 times per day**
 - Receipt of new met file from DAAC
- **Output**
 - Sub-setted met file for processing
- **Information to keep track of**
 - DAAC met file id and version
 - Output met file location, name
 - Dates and times met file covers
 - Resolution of grids
- **Used by**
 - GLAS_EXEC – level 1b, and level 2 processing

PLANNING JOB - CREATE CONTROL FILES

- **Input**
 - Data management
 - Production status
- **Functionality**
 - Check that prerequisites exist for running process and create control file
- **Triggers**
 - Receipt of new data, change in production status
- **Output**
 - Control files
 - Production status update
- **Used by**
 - Each science process and utility has a corresponding planning job

CREATION OF BROWSE PRODUCTS - ONE UTILITY FOR EACH OF THE 15 GLAS STANDARD LEVEL 1 AND 2 PRODUCTS

- **Inputs**
 - GLAS standard level 1 or 2 product granule
 - ANC06 file output from GLAS_EXEC
- **Utility functionality**
 - Create a EOSDIS-type browse product that allows users to see at a glance the overall usefulness of the individual granule – specifics for each granule - TBD
- **Triggers** – automatically triggered each time a product granule is created – hundreds of times/day
 - Creation of any GLAS standard 1 or 2 product granule
- **Output**
 - Browse product that is sent to DAAC along with the product granule
- **Information to keep track of**
 - Browse product file name(s)
 - Product granule id associated with it
 - Location of browse product file(s)
- **Used by**
 - Archived with product granules at NSIDC DAAC
 - SCF data selection and visualization
 - Distributed by SCF to SWT by subscription
 - ST for product QA

CREATE TREND DATA

- **Input**
 - GLA01-GLA15 SCF format
 - ANC06
- **Utility Functionality**
 - Create trend data used to evaluate instrument conditions (there may be several of these utilities, each one dependent on a different set of GLAxx's)
- **Triggers – several times per day**
 - Completion of set of GLAxx's required for each trend data utility
- **Output**
 - Files of data to be plotted to check instrument status
- **Information to keep track of**
 - Trend file names, locations
 - GLAxx granule information (name, version, etc.) associated with each trend file
 - Time span of data

PERFORM AUTOMATIC QUALITY ASSURANCE

- **Input**
 - Browse product for GLAnn
- **Utility functionality**
 - Perform automatic quality assurance – no human intervention
- **Triggers**
 - Completion of a browse product or set of browse products
- **Output**
 - Flags denoting overall quality of product
- **Information to keep track of**
 - Mark data base indicating automatic QA run on this product
 - QA flags for each product

VERIFY PRODUCTS

- **Input**
 - **ANC06**
 - **GLAnn (either scf or HDF-EOS format)**
- **Utility functionality**
 - **Verify that output product contains data expected by creating same statistics from product as those output on ANC06 as product was being created**
- **Triggers**
 - **Completion of product**
- **Output**
 - **Flag indicating product was verified and pass or fail**
- **Information to keep track of**
 - **Flag indicating product was verified and pass or fail**

CREATE HDF PRODUCTS AND METADATA

(one for each GLAS standard product)

- **Input**
 - **GLAS standard product (GLA01-15) in SCF format**
 - **ANC06**
- **Utility Functionality**
 - **Create HDF files with corresponding metadata for each of the GLAS standard product granules**
- **Triggers**
 - **GLAS standard product granule completed**
 - **QA on GLAS standard product granule successfully completed**
- **Output**
 - **HDF files for each GLAS standard product granule**
 - **Metadata for each GLAS standard product granule**

CREATE HDF PRODUCTS AND METADATA

(continued)

- **Information to keep track of**
 - **SCF GLAS product granule dsn**
 - **HDF GLAS product granule dsn**
 - **Dates/Times covered in granule**
 - **Metadata dsn**
 - **Date of creation**
 - **Date sent to NSIDC**
 - **Location of file**
- **Used by**
 - **Procedure that ftps data to NSIDC**

PUSH OR STAGE DATA TO ISF

- **Input**
 - **GLA01-GLA04**
- **Utility**
 - **push or stage data to ISF**
- **Triggers – send once per day or more frequently if required**
 - **Completion of a pre-defined set of above input**
 - **QA successfully completed on all granules in set**
- **Output**
 - **Update production status database**
- **Information to keep track of**
 - **DSN of each granule sent (product id and version)**
 - **Date and time sent**

STAGE DATA TO NSIDC

- **Input**
 - HDF-EOS format of glas standard product granules
 - Metadata for each glas standard product granule
 - Browse data for each glas standard product data
- **Utility**
 - push or stage data to NSIDC
- **Triggers – send once per day**
 - Completion of a predefined set of above input
 - QA successfully completed on all granules in set
- **Output**
 - Update production status database
- **Information to keep track of**
 - DSN of each granule sent (product id and version)
 - DSN of metadata sent
 - DSN(s) of browse data sent
 - Date and time sent
 - Dates of data within each granule

STAGE DATA TO SCF

- **Input**
 - **GLAS SCF standard product granule**
- **Utility**
 - **Push data to SCF data base or stage into area for pulling**
- **Triggers**
 - **Creation of any GLAS SCF standard product granule**
 - **Type 1 QA finished on the granule**
- **Output**
 - **Update production status database**
- **Information to keep track of**
 - **Dsn**
 - **Date it was pushed or staged**
 - **Times of data**
 - **Type of data – GLAxx**
 - **Version number**

I-SIPS COMPUTING FACILITY HARDWARE CONFIGURATION

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I-SIPS FACILITY REQUIREMENTS

- **Process GLAS Level 1 and 2 standard data products at 6x real time. Required specs based on software load analysis:**
 - **CPU specs :**
 - **SPECint_rate95: 720**
 - **SPECfp_rate95: 1080**
 - **I/O throughput:**
 - **10MB/sec sustained write to disk**
 - **6.25MB/sec sustained write to tape**

I-SIPS FACILITY REQUIREMENTS (cont.)

- **Redundant set of hardware with minimal intervention needed for failover to single system**
- **Provide near-line storage for two most recent versions of all GLAS standard data products for the life of the mission**
- **Provide software development and prototyping environment**
- **Highly automated processing system running 24x7 with no third shift operations staff**

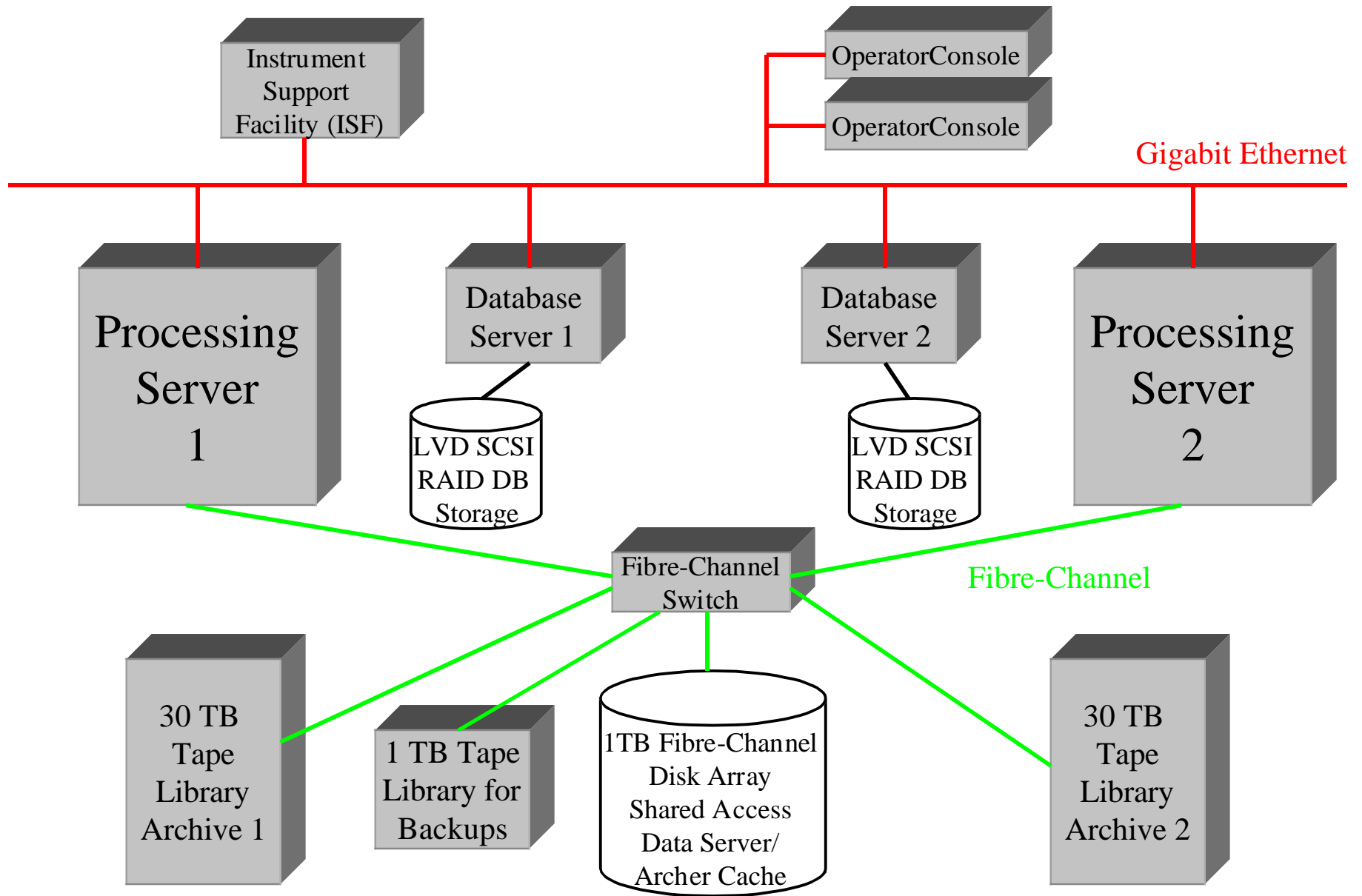
RDBMS

- **Run Oracle Enterprise server to manage the I-SIPS processing and data server, and data archive databases**
- **Cold (offline) backups of databases once per week**
- **Warm (online) backups of databases daily**
- **Use of journaling to maintain all database transactions that occur between backups**
- **Separate, redundant database servers using fully mirrored RAID**

KEY CONSIDERATIONS

- **Large array (>1TB) of file system space shared between main processing servers**
- **High speed networking between all facility computers**
- **High speed networking to GLAS Science Computing Facility (SCF)**
- **Fully operational 6 months prior to launch**
- **Redundant power supplies on all key components**
- **8x5 maintenance contracts with 4 hour turnaround**
- **Systems administrator on duty 8x5, on call all other times.**
- **Have documented procedures for operations staff to perform selected systems administration tasks**

I-SIPS FACILITY CONFIGURATION



HARDWARE SNAPSHOT

Based on Current Technology

- **Processing Servers:**
 - **HP N4000 with (4) PA-8500 440MHz CPUs**
 - **4GB RAM**
 - **SPECint_rate95: 1,209**
 - **SPECfp_rate95: 1,495**
 - **3.8GB/s system bus bandwidth**
- **Clariion FC5XXX Fibre-channel disk array**
 - **15MB/sec host to disk write**
- **Database Servers**
 - **HP L2000 with (2) PA-8500 440MHz CPUs**
 - **2 GB RAM**
- **Archive Tape Libraries**
 - **StorageTek 9710 574 slot, 6 drives, 20TB w/DLT 7000**

PROCUREMENT PLAN

- **Current hardware (HP K580 and K460 servers) will be used for software development, and prototyping**
- **Processing server 1, Tape backup library, LVD disk arrays, and Database Server 1 - 2nd quarter of FY 2000**
- **Tape Archive Library 1- 3rd quarter FY 2000**
- **All other purchases - 1st quarter FY 2001**
- **All hardware in place 6 months prior to launch**

KEY ISSUES

- **Need to determine the best solution that provides shared access to file system space for data server cache area. Current possibilities include:**
 - **NFS - Slow**
 - **GFS - Not yet widely supported**
 - **Various proprietary software and hardware solutions**
- **Current DLT tape library only capable of 20TB**
 - **Super DLT (1st Quarter 2000) will allow 50TB**

LESSONS LEARNED IN VERSION 0

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LESSONS LEARNED FROM VERSION 0

- **Version 0 Development provided insights into activities that will improve the Development process.**
- **Lessons Learned**
 - **Definition of the GLAS Products- Early Freeze Date**
 - **Required for subsystem coding**
 - **Required for subsystem Integration**
 - **Communication: Internal and External**
 - **E-mail, phone, regular meetings, weekly reports.**
 - **Schedule Realistically**
 - **Add “hidden tasks”, buffers, vacation time, holidays**
 - **Use 50% confidence level.**
 - **Have a plan if schedule slips.**

LESSONS LEARNED FROM VERSION 0

(continued)

- Time Allocation. Allow adequate time for updates following Reviews**
 - Program Design Language (PDL) Review**
 - Prototyping and Test Data Creation**
 - Code and Unit Test Plan Review**
 - Unit Test Results Review**
- Emphasis on Prototyping**
 - identify the critical areas and address them**

LESSONS LEARNED FROM VERSION 0

(continued)

- Emphasis on Testing**
 - Adequate planning**
 - Plan Unit Test Early**
 - Acquire test data early**
 - Have a dedicated Tester**
 - Test against the requirements**

I-SIPS SOFTWARE DELIVERY SCHEDULE

- **V0 (Beta) - July 1999**
 - Framework in place, with interfaces for inputs/outputs
 - File formats defined
 - I/O routines written in C
 - F-90 file structures
 - F-90 modules to feed DFDs
 - Dummy calls to DFDs for standalone processing
- **V1 – July 2000**
 - All major functions and interfaces incorporated
 - Any fixes from V0 implemented
 - All ATBDs implemented
 - Functional SDMS with limited archive
- **V2 – December 2000**
 - Complete verified operational I-SIPS software in place
 - Any fixes from V1 will have been implemented
 - Final pre-launch updates to calibration equations implemented

I-SIPS SOFTWARE DEVELOPMENT SCHEDULE

